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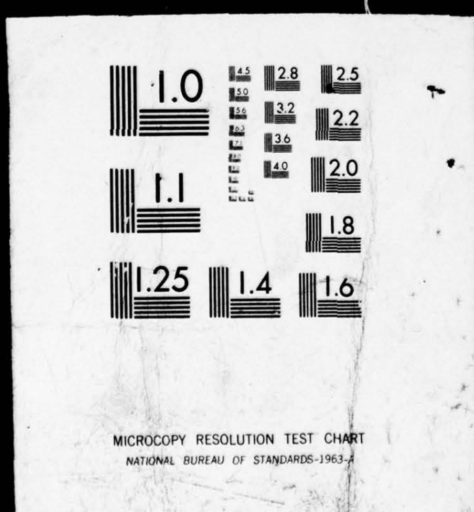

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DEVELOPMENT OF A PROPOSED FLAMMABILITY STANDARD FOR COMMERICIAL TRANSPORT FLIGHT ATTENDANT UNIFORMS

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Final Report

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16. Abstract

The objective of this work was to develop information to support a proposed flammability standard for flight attendant uniforms. Currently used uniforms were found to burn to varying degrees when exposed to a temporary small ignition source. The feasibility of designing uniforms with improved fire safety is demonstrated. Trade-offs in terms of cost, appearance, serviceability, and comfort are discussed. A proposed flammability standard for flight attendant uniforms is included. It describes the tests and qualifying criteria needed to add self-extinguishing characteristics and heat flux resistance to various types of F/A uniform items.

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METRIC CONVERSION FACTORS

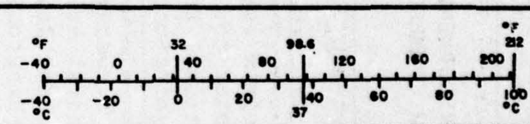
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

The objective of this work was to improve the fire safety of flight attendant (F/A) uniforms. Existing Federal Aviation Regulations require F/As to be aboard air-carrier aircraft in commercial air transportation. Their duties require them to participate in emergency evacuation procedures under post-crash fire conditions. They also participate in extinguishing small in-flight cabin fires which occur due to; e.g., misuse of smoking materials or galley misfunctions. To improve the fire safety of F/A uniforms, they should:

- resist ignition from small ignition sources and
- provide protection against radiative and convective heat.

A "Proposed Flammability Standard for Flight Attendant Uniforms" (which will be called the "proposed standard" throughout this report) is included as Appendix C. The reasons for the various provisions of this proposed standard and the development of the tests are discussed in this report. This work was performed by the National Bureau of Standards (NBS) under an interagency agreement with the Federal Aviation Administration (FAA). The Gillette Research Institute also contributed to the work as a subcontractor to NBS. The test uniforms used to investigate the flammability of existing garments were obtained with the cooperation of the Air Transport Association and Association of Flight Attendants and represent typical styles and fabrics in use in the 1974-1975 period. The contract work statement required the following work to be accomplished:

1.1 Establish the base line hazard of existing uniforms by investigating the flammability characteristics of typical uniforms (and underwear); i.e., conduct burn tests of such uniforms on instrumented mannequins capable of generally assessing the area of injury during a 90-120 second burn period. This is reported in Section 2.1 and Appendix A.

1.2 Identify and evaluate the fire safety of candidate "improved" fabrics--essentially production types possessing acceptable comfort, wearability, cost, cleanability, and other service characteristics. The criteria for the evaluation were to include resistance to radiative and convective heat level, determined from prior cabin fire tests; self-extinguishing features of fabrics; and absence of melt, drip, and heat shrink age characteristics of fabrics (2.2).

1.3 Demonstrate the improved flammability characteristics of typical uniforms made from such fabrics by conducting burn tests on instrumented mannequins similar to those performed under Paragraph 1.1 above (2.3 and Appendix B).

1.4 Make mannequin burn tests, record approximate burn injury data and comparatively tabulate flammability and utilitarian characteristics of currently used versus improved candidate fabrics; identify fabrics which do not pass screening tests, etc.

1.5 Prepare a proposed flammability standard for F/A uniforms based on (a) Consumer Product Safety Commission (CPSC) flammability standard FF 5-74 (children's sleepwear) [1] which is similar to DOC FF 3-71 and Federal Test 5903 and a heat flux resistance test developed by NBS; (b) report data obtained during tests and investigations accomplished under paragraphs above and other requirements of contract work statement.

2. RESULTS AND DISCUSSION

2.1 Base Line Burn Tests of Presently Used F/A Uniforms

The uniforms and underwear used in this phase of the work are listed in Appendix A. Some were new, others used. They included jackets, skirts, slacks, serving aprons, blouses, a raincoat, an overcoat, shirt, tie, panty hose, shoes, boots, and two muumuus. Fibers represented were 100 percent polyester, rayon/polyester, polyester/wool, polyester/cotton blends, acrylic, alpaca, 100 percent wool, and nylon. There were 13 assemblies for female F/As and one male F/A's full uniform. Underwear, socks, hose, and shoes were obtained in local stores and are typical of present use patterns.

The mannequin burns were conducted in two laboratories. One was at NBS with essentially no updraft. The other was at Gillette Research Institute, where a modest updraft existed during burns. One uniform type, a muumuu, was burned in both laboratories and comparative results were obtained. The individual mannequin burns are described in detail in Appendix A which includes a separate report by Gillette Research Institute, dated March 31, 1975.

It should be noted, however, that mannequin burn tests are not completely representative of actual conditions and

have two major deficiencies for estimating the area of the body which would suffer burns in real-life fires. The mannequin remains motionless, while a live person moves in a burn situation. This may aggravate the burn by fanning the fire, but trained persons like F/As would probably attempt to extinguish it. In addition, the number of sensors on the two mannequins used in this project was limited to 24. Consequently, compared to a uniform burn on a live person, only a very rough estimate of the body area burned is obtained. However, the data clearly show that in many cases much less heat is transferred to the body during the first minute of the burn (and little, if any, injury may have occurred in real-life) than might be assumed from viewing the flame of some of the burning uniforms. In other cases, however, the burn injuries would have been perhaps somewhat more extensive than expected because the heat spreads inside the garment ahead of the visible flame on the outside.

The point of ignition on the garment was generally chosen to be at some distance from the mannequin, to represent the most severe condition. Garments in contact or even near a mannequin burn tenuously or not at all because of the heat sink effect of the body and the exclusion of oxygen on one side of the fabric. The same phenomenon has also been observed in burns of simulated garments on anesthetized, shaved rats [2]. Because of the difference in the stance between the two mannequins used (NBS and Gillette) and the differences in the drape of various garments, the point of ignition selected was not always exactly the same. However, in general, the first ignition was in the vicinity of the right knee. If the garment self-extinguished, it was usually again ignited in areas where it was at some distance from the mannequin.

Second-degree burns caused by burning fabrics are generally assumed to occur when the skin has been subjected to a heat flux totaling 2 cal/cm^2 [3]. Higher heat loads cause deeper second-degree and finally, third-degree burns. The heat flux registered by the sensors during the burns of presently used F/A uniforms are shown in detail in the figures of Appendix A, with higher heat flux indicated by deeper shading of the symbols. The estimated areas of second or deeper burns found in these mannequin experiments varied as follows:

30 seconds after ignition: 0 to 5%
60 seconds after ignition: 0 to 25%
90 seconds after ignition: 0 to 30%

The figures in Appendix A also indicate the areas of the mannequin on which burning was observed on the outside of the uniforms, to permit comparison of heat flux data and visual observations.

Even the upper levels of estimated burn areas are smaller than those obtained in other mannequin tests [2,3] when dresses containing cotton or polyester/cotton fabrics were burned. The latter two materials generally burn faster for a given weight and garment construction than most of the materials normally used in current F/A uniforms. A cursory review of the materials used in current F/A uniforms revealed only two garments which are often (but not always) made from polyester/cotton fabric--serving aprons and raincoats. Both garments were burned on mannequins. In one case, the serving apron was fitted tightly at the waist and worn over a fairly heavy polyester/wool uniform (Burn No. 8-1). In this configuration, the burn started slowly, and relatively little heat was transferred to the mannequin. The other serving apron was looser (Burn No. 6-3), and more heat was transferred to the mannequin. The raincoat had a thick, heavy alpaca lining (alpaca is an animal fiber and is chemically, practically identical to wool). While the coat burned fiercely on the outside, no heat was measured on the inside by Gillette Research Institute (Burn No. 10-1). The heavy lining, jacket, shirt, and underwear apparently provided sufficient insulation from the burn. However, it should be noted that the hot gases from the flames could envelope the face (no sensors located there) and cause severe injury or death from inhalation of hot, toxic gases. On the other hand, a F/A would probably have taken defensive action, by taking the garment off or some other protective response. In another raincoat fire, without the lining, more potential injury was measured (Burn No. 10-2). Other uniforms which burned relatively rapidly and with significant heat output were an acrylic tunic and slacks (Burn No. 4-1) and uniform items made from polyester/wool blends (Burn No. 12-2).

Uniform items made from 100 percent polyester or nylon generally burned tenuously and often self-extinguished. In such fabrics, a hole was formed by the ignition source, and the flames were usually confined to the edges of this hole. The flames often increased the hole in size, particularly downward, and melt drip often fell and ignited other areas of the garment, but potentially injurious heat transfer to the mannequin was essentially limited to the area of the burning ignition source or underwear which caught fire.

All details of the characteristics of the uniforms, the observations during the burns, and the figures indicating the estimated areas of burn injury are contained in Appendix A.

2.2 Fire Safety of F/A Uniforms--General Considerations

The preceding section discussed potential injuries which could occur if presently used F/A uniforms are exposed to small ignition sources. Some of the uniforms burned and could inflict substantial burn injuries unless extinguished or removed during the early stages of the fire. Other uniforms, those containing nylon and polyester, were essentially self-extinguishing. However, such thermoplastic fibers shrink, soften, and melt at temperatures below the ignition temperature of fibers in general. Fabric heat shrinkage and softening are undesirable in garments which may be exposed to heat flux because they reduce the insulating air layer between garment and wearer [4,5]. Fabric integrity (and thus the ability to protect the wearer from heat flux) is lost when thermoplastics melt and drip [4].* The melt drip may continue to burn and ignite lower body garments or other materials. Softened or molten material can also stick to the skin and can cause injuries even if the fabric does not burn [6]. Thermoplastic fibers, such as nylon and polyester, generally do not provide even a modest amount of protection against flame and heat flux. Consequently, fabrics intended for F/A uniforms should be screened in the following manner:

- by means of a test which establishes self-extinguishing characteristics; i.e., assures that they will not continue to burn when the ignition source is removed. A well-established test, FF 5-74, was modified for this purpose in the proposed standard, as discussed in 2.4 and

- by means of a heat flux resistance test, in which the fabrics are subjected to certain levels of heat flux, and their insulation characteristics as well as their resistance to loss of integrity (melting) can be measured. For this purpose, NBS developed the test for heat flux resistance described in the proposed standard. The pass-fail levels for this test were chosen so that presently available fabrics (though not

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* This behavior was observed during several mannequin burns, described in Appendix B, where placing an ignition source in the front of flame-resistant treated polyester blouses lead to ignition of the bra after the blouse melted away.

those used at present in F/A uniforms) would qualify. The trade-offs between fire safety and other functional fabric characteristics are described in 2.3, below.

2.3 Flame-Resistant Fabrics

This section discusses the availability, advantages, and disadvantages of present-day flame-resistant (FR) fabrics. Flame-resistant materials are here defined as those which would rapidly self-extinguish after being ignited by a non-persistent, small ignition source. The protection afforded by these materials against heat flux when not exposed to ignition sources varies widely, as discussed in Section 2.4, below.

At present, there are essentially only two markets for FR fabrics--children's sleepwear, which must be FR by law, and protective garments. The latter include garments worn by steel mill workers, fire fighters, fuel handlers, race drivers, etc. Each has its own set of requirements but none has the "fashion" requirement of F/A uniforms. However, the major retailers and garment manufacturers have recently announced plans to introduce lines of FR garments for the general public within the next year or two. This is done presumably to test the demand.

Table 1 lists presently available FR fabrics. They vary in state of development from pilot scale to commercial. The information on the various characteristics of the fabrics was obtained from discussion with industry representatives, at meetings, or textile literature. This tabulation does not include information on the toxicology of the fabrics.

The statements in the column, "Effect of Heat", represent the general behavior of the fibers or fabrics, as obtained from the manufacturer or the general literature. The specific response of some of these fabrics in NBS testing is discussed under 2.4.2, below.

Similarly, the entries in the columns headed appearance, ease of care (washability, need for pressing, etc.), serviceability, and comfort characteristics listed in the table are general statements. They are affected by constructions and finishes. For example, some colors on Nomex may fade, others may be very stable. Some individuals would rate the comfort of 100 percent polyester acceptable, especially in view of the other desirable fabric properties, but others would rate it low.

Table 1

Properties of Candidate Fiber Materials for Flight Attendant's Flame and Heat Resistance Uniforms[1]

FR Fabric	FR Status	Effect of Heat	Appearance: Wrinkling, Drape, Etc.	Appearance: Color Range	Ease of Care	Serviceability	Comfort	Economics	Possible Use in F/A Uniforms
Acetate	Commercial	Sticks at 350-370° F Melts at 500° F	+	+	0	-	+	+	Not recomm. (appearance, serv., ease of care, heat shrinkage).
Aramid (Nomex)	Commercial	Shrinks at 630° F and Chars	+	-[4]	0	++	-	--	All types of garments.
Cotton	Commercial	Chars	--	++	--	-[7]	++	0	Underwear only (appearance, ease of care).
Modacrylics	Commercial	Stiffen, shrink at 250-400° F	-	-	--[5]	-	+	+	Not recomm. (appearance, ease of care).
Novoloid (Kynol)	Semi-commercial	Chars at 570° F	--	--[3]	?	--	?	--	Not recomm. until further development.
Nylon 6	Commercial	Melts at 420-430° F	+	++	+	++	0	++	Not recomm. (heat shrinkage).
Nylon 66	Commercial	Sticks at 445° F Melts at 480-500° F	+	++	+	++	0	++	Not recomm. (heat shrinkage).
Polyester	Commercial	Sticks at 440-470° F Melts at 480-510° F	++	++	++	+[8]	+	++	Not recomm. (heat shrinkage).
Rayon	Pilot	Chars	--	0	--	-	++	-	Underwear only (appearance, ease of care).
Triacetate	Commercial	Sticks at 350-460° F Melts at 570° F	+	+	+	-	+	+	Not recomm. (appearance, serv., ease of care, heat shrinkage).
Wool	Pilot	Chars	+[2]	++	-[6]	+	++	--	Jackets, slacks, wintercoats, skirts.

Table 1 (con't)

FR Fabric	FR Status	Effect of Heat	Appearance: Wrinkling, Drape, Etc.	Appearance: Color Range	Ease of Care	Serviceability	Comfort	Economics	Possible Use in F/A Uniforms
BLENDS:									
Wool/Polyester (75/25)	Pilot	Chars	++	+	0	++	++	-	Looks promising for jackets, slacks, overcoats.
Polyester/ various fibers (Kohjin, Leavyl, modacrylics, etc.)	Commercial	Appear to have little, if any, advantage over 100% polyester for this end-use.							
Polyester/FR rayon	Exp.	These would be blends of FR rayon and FR polyester fibers; could be promising if developmental problems are overcome--economics, etc.							
Aramid/ Novoloid	Exp.	High heat resistance, but presently poor in appearance, economics. Further development may improve this product.							
Polyester/ Cotton	Exp.	Not useable at present state of development (appearance, comfort, economics).							

1 All the materials mentioned here are either innately flame resistant or flame resistant treated. In many cases, the fibers are flammable (e.g., cotton, acetate, rayon) when not treated.
2 Looses crease, wrinkles when moist.
3 Color fading seems to be a severe problem at present.
4 Some colors may fade, somewhat limited color range at present.
5 May stiffen and shrink in coin-op laundering and drycleaning.
6 May shrink and loose crease in laundering; o.k. in drycleaning.
7 Depends on type of FR treatment.
8 ++ Except for possible snagging and bagginess of knits.

++ Considered Excellent + Considered Satisfactory 0 Considered Marginal - Considered Poor -- Considered Very Poor
? Reliable Information Not Available

NOTE: The information in this chart was collected from a wide variety of persons and literature in the industrial and in the home economics field as well as the general literature. For each fiber type, the general description given above can be somewhat affected by fabric construction and finish.

The cost of improved F/A uniforms, made from FR materials, cannot be readily predicted. The fabrics listed in Table 1 vary in price from $1.50/yard for the cheaper polyesters to $6/yard for Nomex and wool. This compares with recent prices for presently used F/A uniform fabric starting at $1.50/yard for polyester double knits and $3/yard for polyester/wool blends. For each fabric type, the prices can increase significantly for specific styles, prints, or colors.

The major factor in price increases may be the garment manufacturer's markup. Our discussions with fabric producers and the billings from the uniform manufacturers indicate that the uniforms cost very roughly 10 times the cost of the basic fabric. This multiplier, of course, includes additional materials such as linings, innerlinings, and sewing thread, as well as labor, overhead, and profit. The final price of the improved uniforms would thus depend whether the manufacturer just adds the additional cost for the FR fabric or whether he uses other multipliers in his price determination. More specifically, it appears that the increase in price for improved uniforms could vary from a few dollars to more than double the present price.

The last column in the table contains specific recommendations for use of the various FR fabrics in F/A uniform items. Basically, it appears that Nomex or equivalent products could be phased in soon in blouses and perhaps later in jackets and slacks. This would require some restyling of present Nomex fabrics which are mostly designed for protective clothing and sleepwear used in Veterans Administration hospitals. With proper styling, the comfort of Nomex could be similar to that of polyester and its protective value increased. This could be accomplished by choosing a rougher surface, at least on the side worn next to the skin. Nomex fabrics may not be as wrinkle free as polyester, but it appears that methods to improve their "permanent press" characteristics are being developed. The "pilling" problem has been at least partially overcome. Color choice may be limited. Serviceability should be excellent. The FR characteristics of Nomex would not be expected to change with age, laundering, or drycleaning.

Wool is presently used in some crew uniforms. Wool fabrics do not burn readily, unless they are very lofty or fuzzy. A treatment has been developed to increase the natural flame resistance of wool. Apparently, this treatment has not yet been used in full-scale production for apparel though a similar treatment is used for aircraft upholstery. Some initial delays may be encountered in producing commercial quantities.

The cost of the treatment is modest. In tests conducted by NBS, resistance to drycleaning seemed satisfactory. Wool fabrics wear well, do not soil easily but tend to shrink and wrinkle in machine laundering; are available in many colors; and their comfort characteristics are generally considered excellent. Wool fabrics, especially in lightweights, tend to wrinkle more than polyester double knits. Flame-resistant wool may be a satisfactory alternative to Nomex in this market, especially in slacks and jackets.

Wool/polyester blends, with 50 or more percent of polyester, are used in F/A uniforms at present. This blend burns quite readily, and no FR treatment has been developed. However, the treatment developed for 100 percent wool fabrics apparently is quite effective for fabrics containing lesser percentages of polyester, up to 25 percent. Such materials could be expected to have better wrinkle resistance than 100 percent wool. Not enough of this experimental fabric was available to investigate it in depth, especially the effect of the melting of the polyester component at higher heat flux. No recommendations can be made at this point regarding its use in F/A uniforms.

The bulk of present blouses, slacks, skirts, jackets, etc., is cut from 100 percent polyester fabric. These fabrics are used in F/A uniforms because they are relatively cheap, are available in a variety of colors and styles, have superior wrinkle resistance, and have permanent press characteristics. Most wearers like the comfort of polyester fabrics. Disadvantages are snagging and bagginess in some constructions. In spite of their popularity, they cannot be recommended for fire-safe F/A uniforms because of their low resistance to heat flux, as discussed under 2.2, above. As a case in point, in mannequin burns described in Appendix B, FR polyester blouses melted away in the area of the ignition source, the bra caught fire, and in turn, caused additional burning and melt dripping of the blouse. A Nomex blouse did not loose its integrity to the same extent and protected the bra from ignition.

The FR cellulosic fabrics, FR cotton and FR rayon, at present, have such poor wrinkle resistance that they should not be considered for F/A outer-wear. They could be used in linings and underwear. Blends of FR rayon and FR polyester have been produced on an experimental scale and should have adequate appearance properties.

Fibers such as FR acetate, Kohjin, Leavyl, modacrylics, etc., may not perform adequately under heat flux because of their low melting point.

In summary, certain wool and Nomex fabrics appear to be promising candidates to increase the fire safety of F/A uniforms. The acceptance criteria in the proposed standard are based on their performance in laboratory screening and mannequin tests. Other fabrics which qualify under the proposed standard may become available in the future.

2.4 Development of Qualifying Tests for the Proposed Standard

2.4.1 Self-extinguishment

The Interagency Agreement required incorporation of a vertical flammability (self-extinguishment) test into the proposed standard. The FF 5-74 [1] was chosen because it is the most widely used test of this kind. In the FF 5-74 test, fabrics are mounted in a U-shaped specimen holder and suspended vertically. A gas flame is brought in contact with the bottom edge of the fabric for 3 seconds. Upward char length exceeding 7 inches constitutes failure. The wording of the FF 5-74 was used in the proposed standard to the greatest possible extent, except where modifications were necessary to make it applicable to F/A uniforms. The modifications are discussed below.

The FF 5-74 test was designed to protect children who are not generally expected to act rationally in a fire situation. Consequently, it was designed to be a severe test and does not qualify many fabrics which burn only tenuously, with little heat development and which are easily extinguished. Such fabrics may not present a significant hazard to a well trained F/A. One of the most difficult provisions of FF 5-74 is the inclusion of seams in the test program. However, since FF 5-74 has been promulgated, it has been found, in experiments at NBS and other laboratories, that seams in fabrics which pass this test are unlikely to inflict burn injuries to significant body areas, especially if defensive action (e.g., blowing or slapping at the fire) is taken. Consequently, the seam testing requirement has been omitted from the proposed standard because seam burns do not appear to present an unreasonable risk, and the seam testing requirement is a major burden for the garment manufacturer.

On the other hand, the FF 5-74 test was developed before thermoplastic fibers, such as nylon and polyester, were widely

used in children's sleepwear. Ignition is at the bottom of the specimen and downward or sideward burning, which occasionally occurs in thermoplastic fabrics, cannot be readily observed. However, such fabrics do not qualify under the provisions of the heat flux resistance test of the proposed standard and would thus not qualify for F/A uniforms even if they should pass FF 5-74.

The FF 5-74 requires qualification of fabrics and garments before and after laundering but omits drycleaning. However, since F/A uniforms are often drycleaned, a drycleaning procedure recently developed by NBS has been included in the proposed standard. Since many garments labeled "Launder Only" are sometimes drycleaned and others labeled "Dryclean Only" are occasionally laundered, the proposed standard requires that a fabric qualify after both laundering and drycleaning.

A requirement that fabrics qualify with ignition times of 3 as well as 12 seconds. It has been shown that some fabrics will ignite in 3 but not 12 seconds [7], while an experimental fabric which could be considered for F/A uniforms, a blend of FR polyester and FR rayon, ignited in 12 but not at 3 seconds in NBS tests. Thus, 3 and 12-second exposures do not seem unreasonable for the present objective.

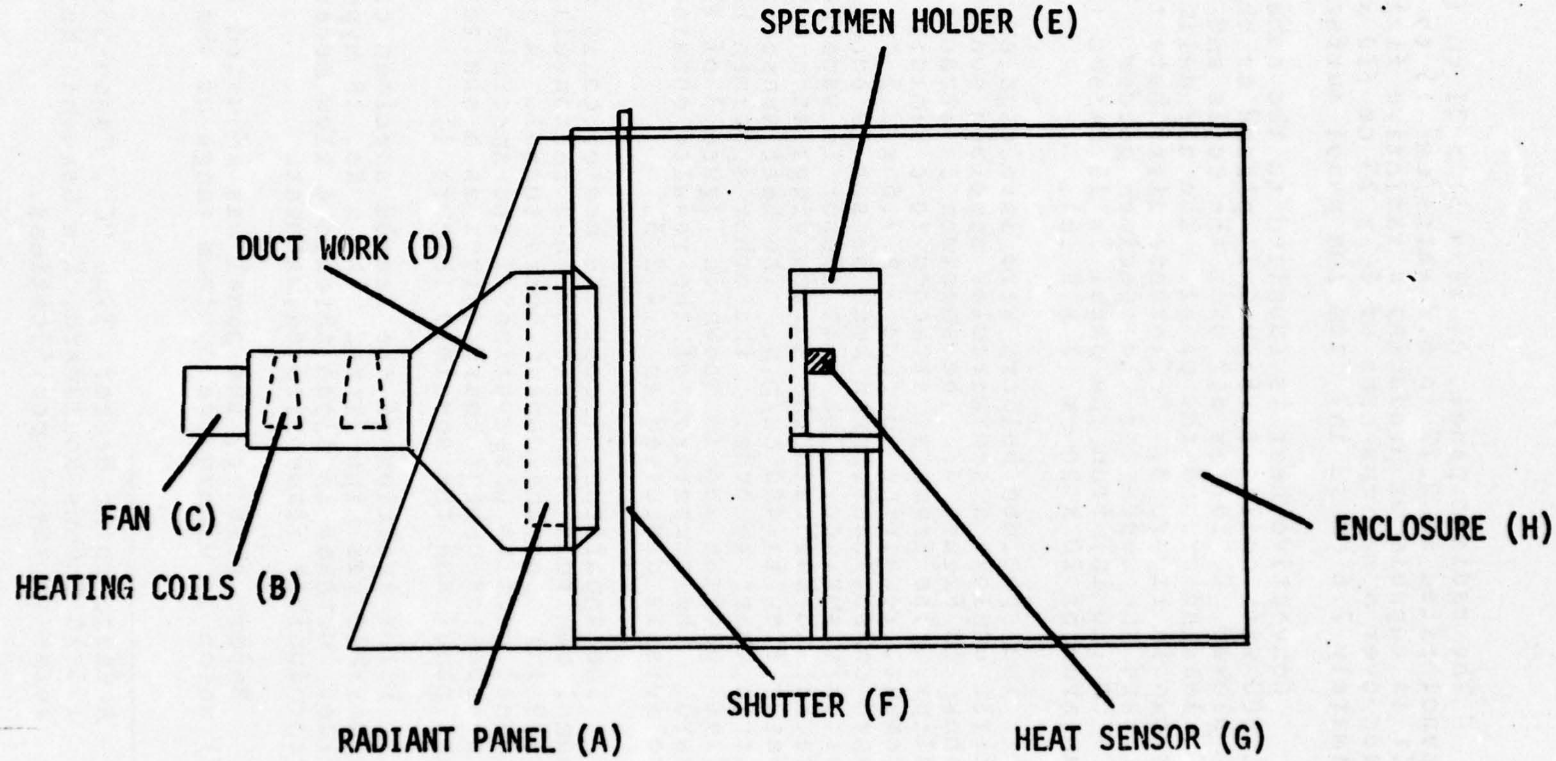
2.4.2 Heat Flux Resistance of Fabrics

The work described in this section was conducted in order to develop a test method for the evaluation of the insulative or protective value of fabrics. Apparatus was designed and used for the testing of a number of FR fabrics under a variety of test conditions. The results were used in the writing of the proposed standard (Appendix C).

2.4.2.1 Apparatus

The apparatus consists of a radiant panel with controls, heating coils, fan, duct work, a specimen holder, a pilot igniter, a shutter, a heat sensor, and the enclosure (Figure 1).

FIGURE 1: SCHEMATIC DIAGRAM OF APPARATUS



The radiant panel, A, is a 31 x 31 cm (12 x 12 in) quartz panel rated at 0.77 to 6.2 watts/cm^2 (5 to 40 watts/sq in).* It is capable of producing a radiative field of 0.40 cal/cm^2 sec over a maximum area of 25 x 25 cm (10 x 10 in) at approximately 7.6 cm (3 in) from the panel surface.

Convective heat is supplied to the same area by four 1,000 watt coils, B, Figure 1; placed as shown in Figure 2. A blower, C, forces air over the coils and into the duct work, D, leading around the panel. The air delivery openings are shown in Figure 3. Deflectors distribute the heated air toward the center of the specimen holder. The air speed at 25 cm (10 in) from the panel is 15 cm/sec (300 ft/min) over an area of 20 x 20 cm (8 x 8 in).

Two specimen holders were investigated in this work. The first employs a semicircular specimen configuration and is shown in Figure 4. The specimen is attached to the frame by clips. The frame is attached to a semicircular, asbestos-cement, receiving surface. A 7.6 x 2.5 cm (3 x 1 in), blackened copper/Constantan heat sensor is embedded in the center of this surface. The heat sensor is water cooled with a water jacket to maintain the surroundings at a constant temperature. Water flow is 400 cc/min. The heat sensor is connected to a strip chart recorder. The other specimen holder employs a flat specimen and is *shown* in Figure 3 of the proposed standard. The comparison of the results obtained with these two holders is discussed in 2.4.2.3.

The apparatus, except the heater coils and the radiant panel controls, is enclosed in a rectangular 55 x 50 cm (21 x 19 in) asbestos-cement board tunnel. A glass window in the tunnel permits observation of the specimen during exposure. An asbestos-cement board serves as a shutter between the radiant panel and the specimen (Figure 1).

Pilot ignition of the heated specimen can be achieved by a movable gas pipe fitted with a No. 18 hypodermic needle orifice. Methane is piped through a flow meter and valve for reproducible flame size adjustment.

Before testing, the panel was adjusted to 912° C (1,670° F) which is within the optimum range of the radiant source.

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* A Casso-Solar Heater, Type "C", Casso-Solar Corporation, 125-10 Queens Boulevard, Kew Gardens, New York 11415, conforms to these specifications.

FIGURE 2: APPARATUS USED TO MEASURE PROTECTION VALUE OF FABRICS
THERMAL SUBASSEMBLY
SIDE VIEW

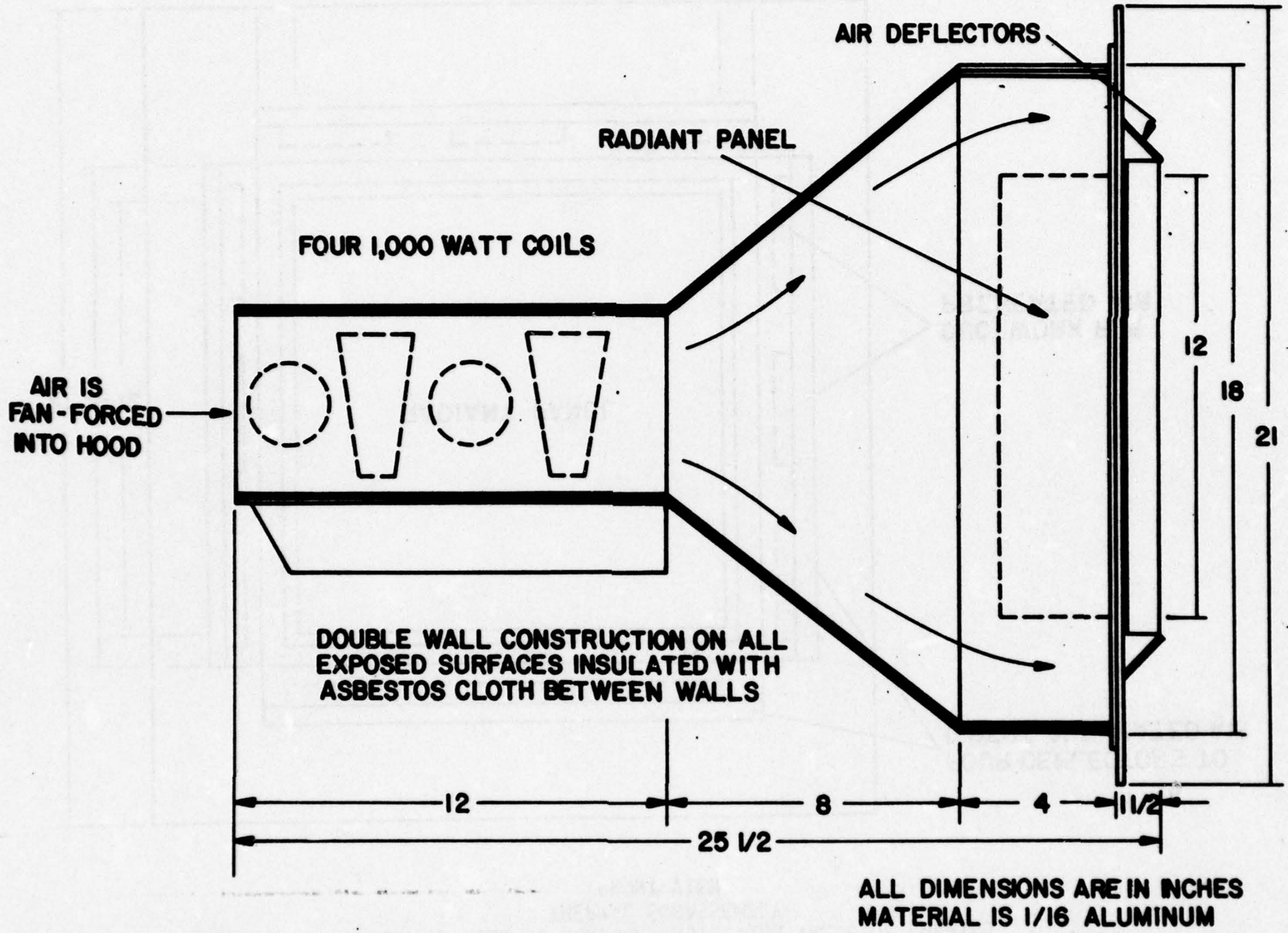


FIGURE 3: APPARATUS USED TO MEASURE PROTECTION VALUE OF FABRICS
THERMAL SUBASSEMBLY
FRONT VIEW

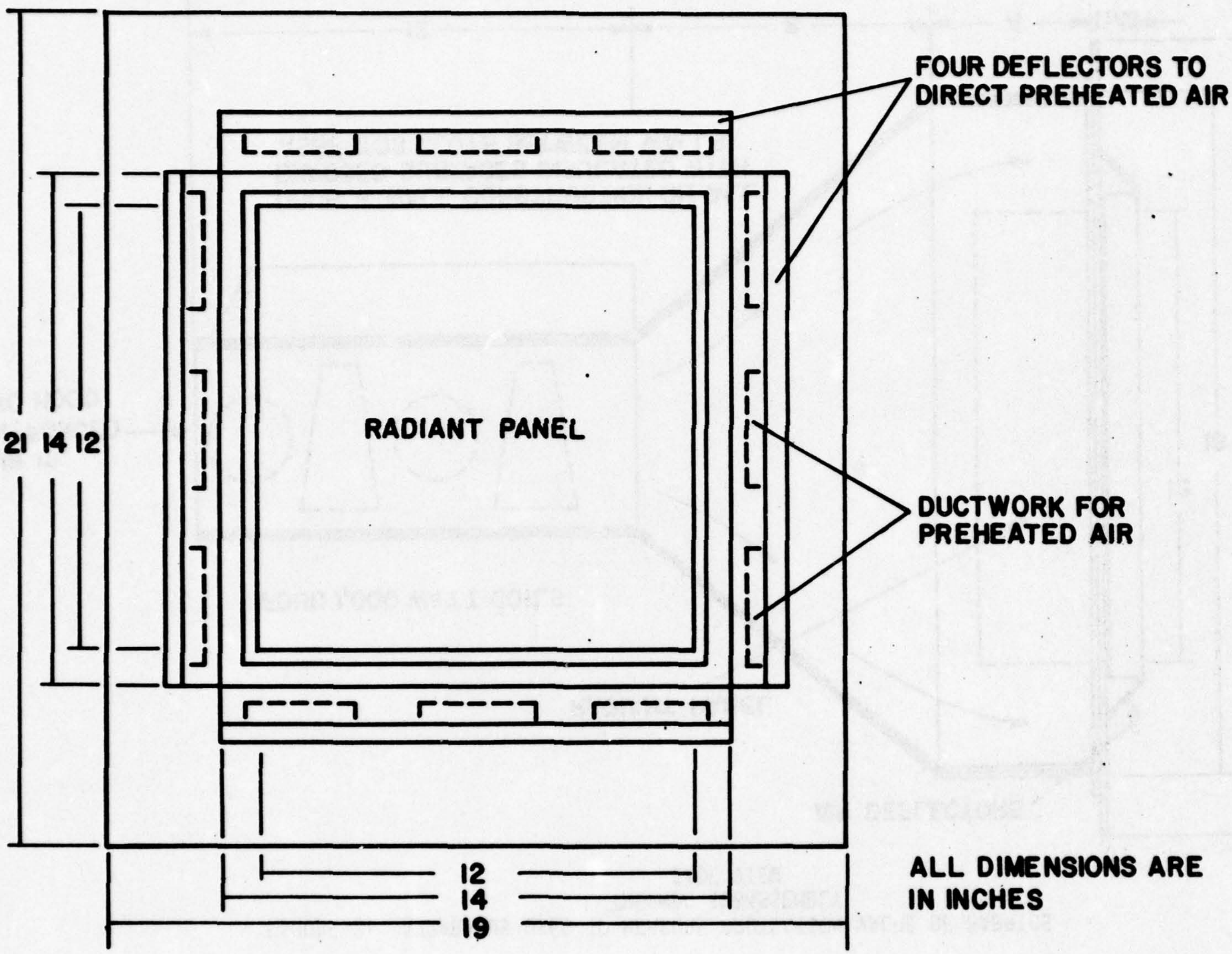
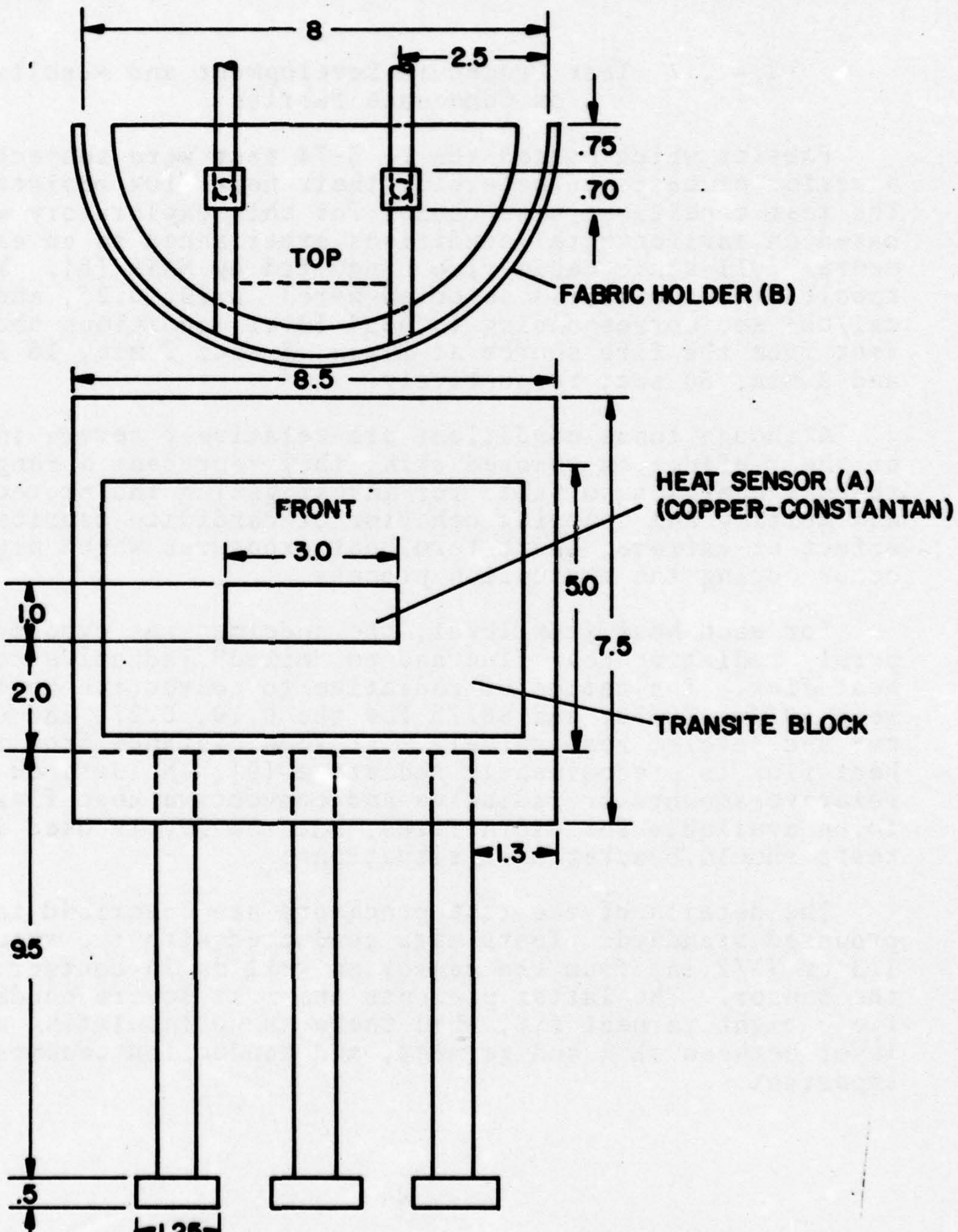


FIGURE 4: SPECIMEN HOLDER

ALL DIMENSIONS ARE GIVEN IN INCHES
ALL MATERIAL IS ALUMINUM UNLESS OTHERWISE NOTED



The distance from the panel at which the desired heat flux is attained was determined. The specimens were exposed to this heat flux for 2 minutes. Conceptually, at this time, all fabrics which could be used in F/A uniforms would no longer protect the F/A against burns. (The heat flux behind the specimen was determined from the recorder chart every 5 seconds.) A specially written computer program plotted a curve showing time vs. total heat measured behind the fabric. (Figures 5-8)

2.4.2.2 Test Procedure Development and Results on Candidate Fabrics

Fabrics which passed the FF 5-74 test were subjected to a series of tests to determine their heat flux resistance. The test conditions were chosen for this exploratory work based on environmental conditions experienced in an experimental full-scale cabin fire conducted by NASA [8]. The specific test criteria selected were: 0.19, 0.27, and 0.40 cal/cm^2 sec corresponding to head level conditions about 6 feet from the fire source at 2 min, 8 sec; 2 min, 16 sec; and 2 min, 30 sec; respectively.

Although these conditions are relatively severe in terms of their effect on exposed skin, they represent a range of thermal energies suitable for investigating the protective and melting and charring behavior of candidate fabrics; i.e., effect of extreme, short-term heat exposures which might occur during the evacuation process.

For each heat flux level, the specimen was exposed to purely radiative heat flux and to "mixed" radiative-convective heat flux. The ratios of radiative to convective heat flux were 60/40, 70/30, and 80/20 for the 0.19, 0.27, and 0.40 cal/cm^2 sec levels, respectively. At some distance from fires, heat flux is predominantly radiative [9]. No data on the relative amounts or radiative and convective heat flux seem to be available for cabin fires, but the levels used in our tests should bracket most situations.

The details of the test procedure are described in the proposed standard. Tests were conducted with the specimen 1.3 cm (1/2 in) from the sensor as well as in contact with the sensor. The latter presents the most severe condition; i.e., tight garment fit, when there is no insulating air layer between skin and garment, and conduction becomes important.

2.4.2.3 Test Results and Discussion

Typical curves of time-heat received at the sensor are shown in Figures 5 through 8. Also shown in each figure is a solid curve indicating the expected time-incident heat relationship which could cause a second-degree burn. If, for any given time since initial exposure to heat, the heat transferred through a fabric exceeds the value shown on the curve, a second-degree or deeper burn could be expected. Values below the curve would indicate no injury; i.e., effective protection at the given time. The curve is based on animal and human data and presents a general case [10]. Actual times to second-degree burn varies with skin thickness which, in turn, varies greatly between individuals and over various parts of the body. This curve illustrates the manner in which time to second-degree burn depends not only on the total heat received by the skin but also on the rate at which it is received. It seemed important to consider this in the present research on the relative protective value of fabrics.

The heat sensor was calibrated with a commercial heat flux meter. In addition, a few trials were made in which human hands were exposed to the heat flux behind various fabrics in the same relative position to the fabric as the heat sensors used in this work. The time until pain was first felt and the time to withdrawal of the hand were recorded. Each subject exposed the inside and the outside of both hands. Pain generally occurs several seconds before the onset of second-degree burns; it is, however, a very subjective concept. (Burn victims sometimes do not report pain sensation during the fire.) Considering the variability of such subjective experiments and the difference between time to pain and time to second-degree burn, the sensor used in our experiments seemed to rank fabrics in a reasonably similar manner to the human trials.

Figure 5 shows the measurements made with the curved heat sensor behind nylon hose in contact with the sensor, exposed to 0.19 cal/cm^2 sec. The time-heat flux line initially follows the second-degree burn line quite closely and crosses it at about 15 seconds. This indicates that, under these conditions, a second-degree burn may be suffered in 15 seconds when wearing such stockings, which, incidentally, is roughly the time it would take to burn bare skin. At 0.40 cal/cm^2 sec, this time would be about 5 seconds. The projection on the time axis at which the heat flux/time curves registered by the sensor exposed behind various fabrics crossed the second-degree burn line will be called the "heat flux resistance" throughout this report.

FIGURE 5: NYLON HOSE AT TWO INCIDENT HEAT FLUX LEVELS, MIXED MODE ONLY, WITH BURN THRESHOLD CURVE

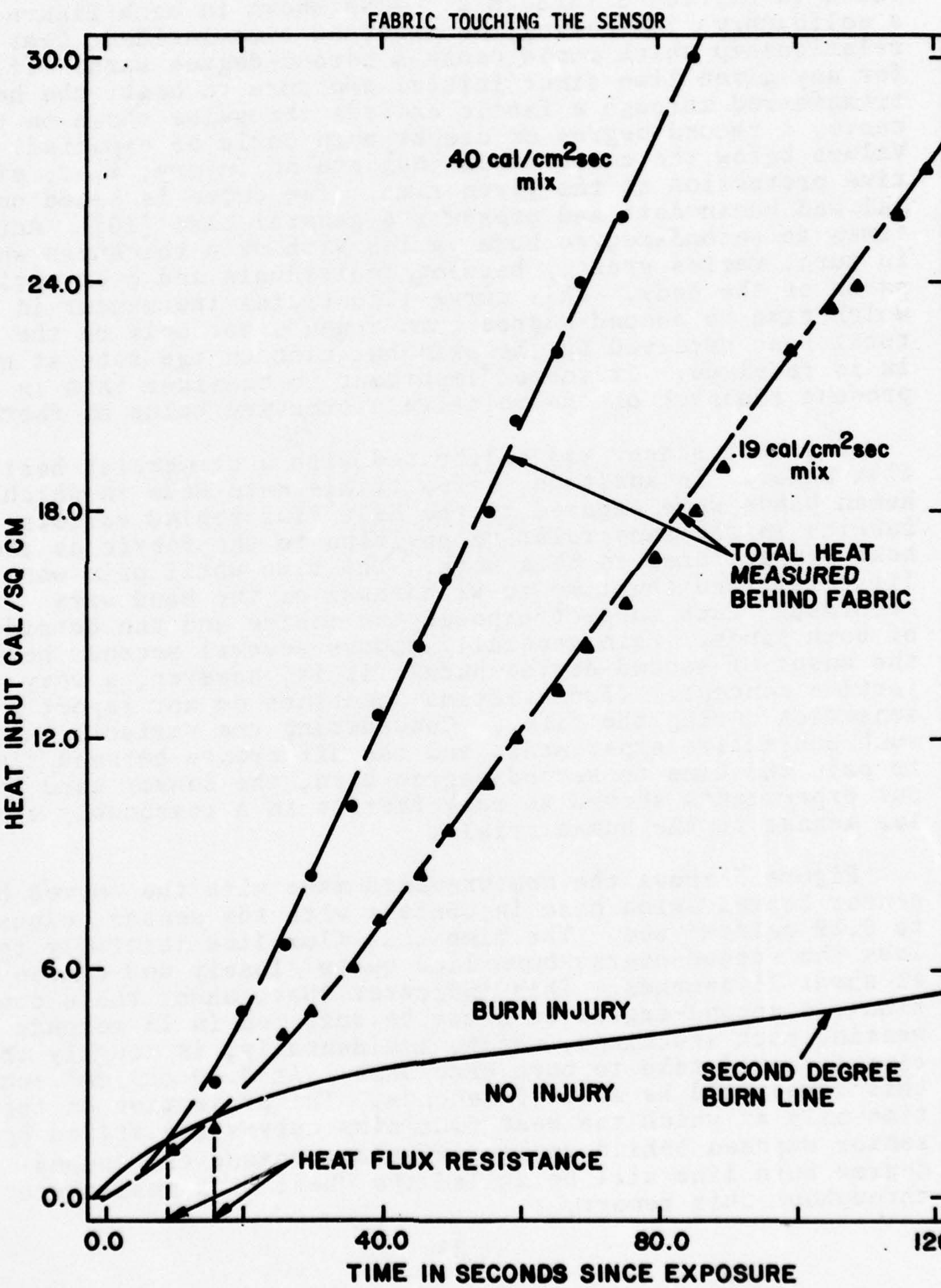


FIGURE 6: 100% POLYESTER, FR FINISH AT TWO INCIDENT HEAT FLUX LEVELS (BOTH RADIANT AND MIXED MODES) WITH BURN THRESHOLD CURVE

FABRIC-SENSOR DISTANCE 1/2"

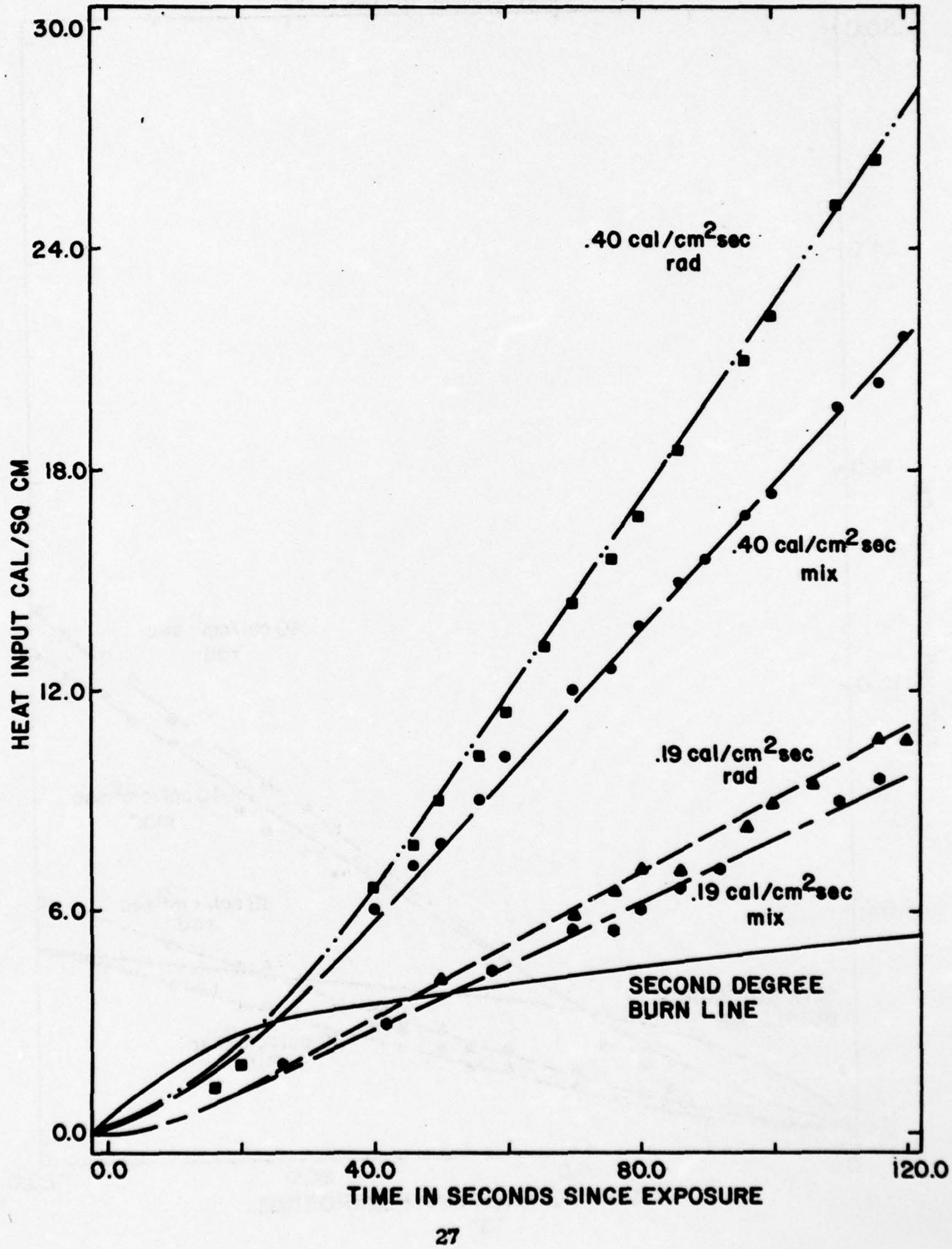


FIGURE 7: 100% NOMEX AT TWO INCIDENT HEAT FLUX LEVELS (BOTH RADIANT AND MIXED MODES) WITH BURN THRESHOLD CURVE

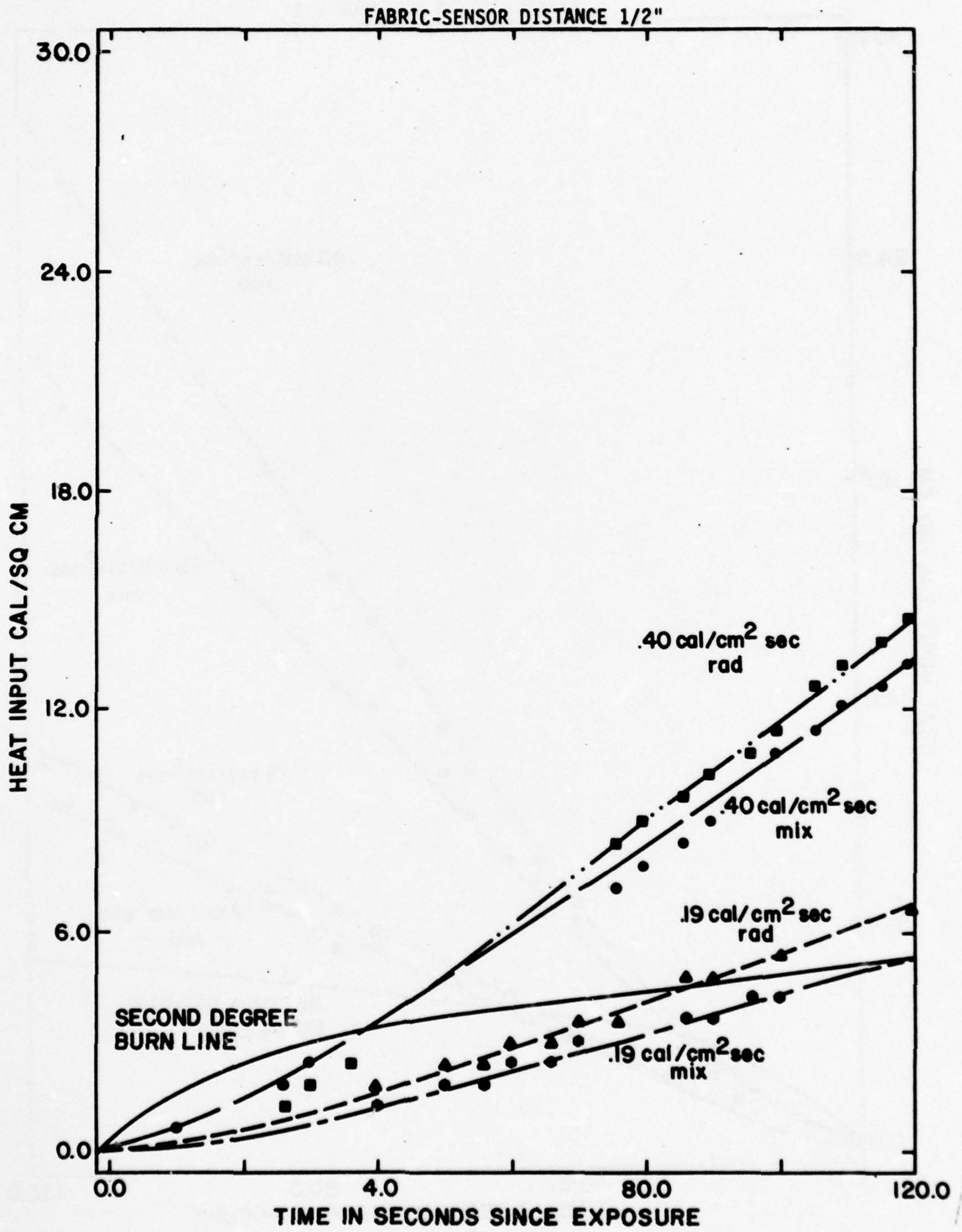
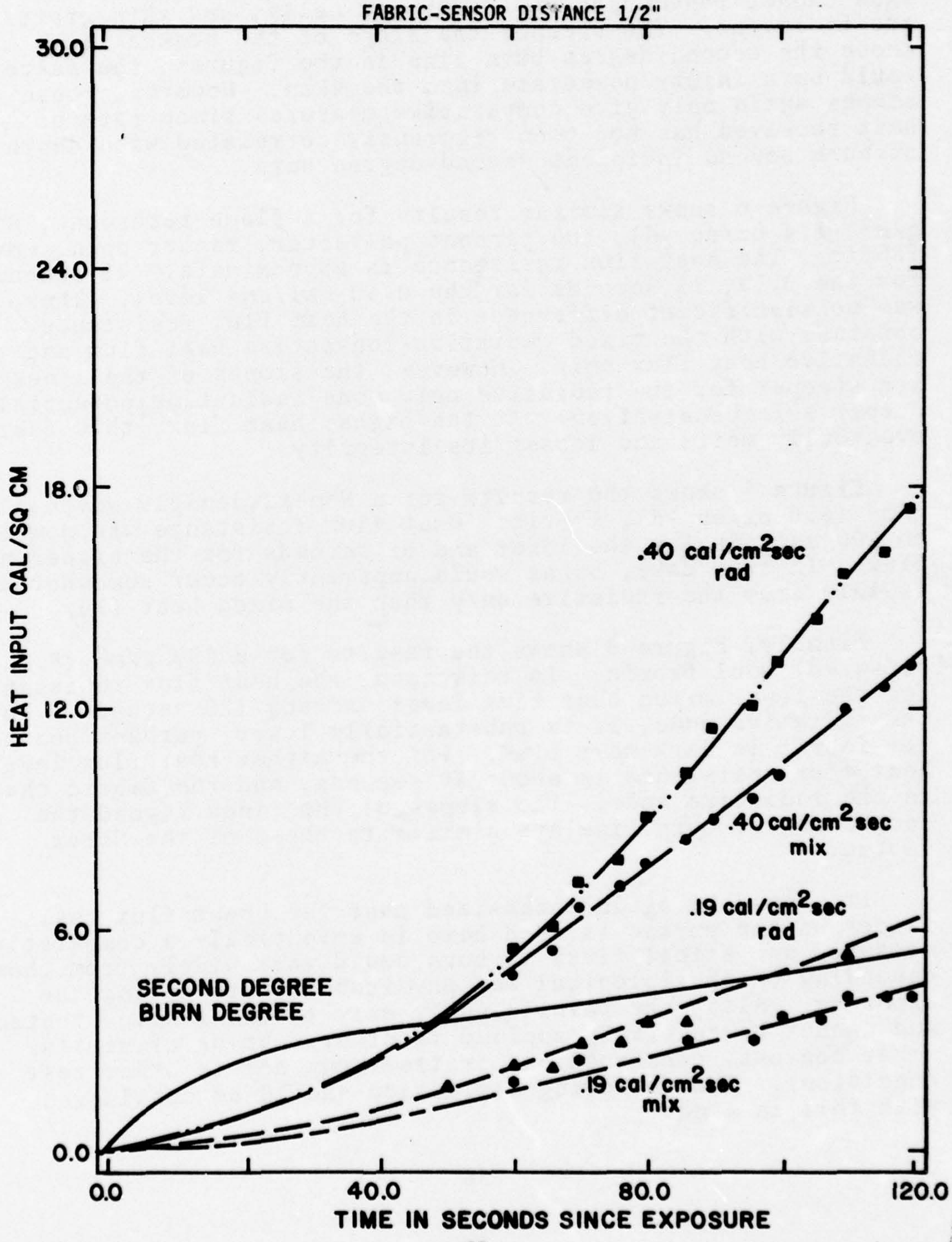


FIGURE 8: 100% WOOL, FR TREATED, AT TWO INCIDENT HEAT FLUX LEVELS (BOTH RADIANT AND MIXED MODES) WITH BURN THRESHOLD CURVE



The term "second-degree burn" generally indicates burns which do not require skin graft but covers a range of depth of burns and, consequently, varying rates of recovery. Third-degree burns generally indicate a burn deep enough so the skin cannot regenerate the destroyed cells, and skin grafts are indicated. The steeper the slope of the broken lines above the second-degree burn line in the figures, the faster would burn injury penetrate into the skin. However, these slopes again only give comparative measures since rate of heat received has not been rigorously correlated with depth of burn beyond incipient second-degree burn.

Figure 6 shows similar results for a flame-retardant, 81 g/m^2 (2.4 oz/sq yd), 100 percent polyester, rather open, woven fabric. The heat flux resistance is approximately 45 seconds for the 0.19, 25 seconds for the 0.40 cal/cm^2 level. There was no significant difference in the heat flux resistance obtained with the mixed radiative-convective heat flux and the radiative heat flux only. However, the slopes of the lines are steeper for the radiative only mode indicating potentially deeper skin penetration. At the higher heat flux, this fabric eventually melts and looses its integrity.

Figure 7 shows the results for a Nomex, densely woven, 168 g/m^2 (5.0 oz/sq yd), fabric. Heat flux resistance was now 80 to 100 seconds for the lower and 35 seconds for the higher heat flux. In this case, burns would apparently occur somewhat more rapidly from the radiative only than the mixed heat flux.

Finally, Figure 8 shows the results for a 290 g/m^2 (8.7 oz/sq yd) wool fabric. In this case, the heat flux resistance for the lower mixed heat flux level exceeds 120 seconds. For the radiative mode, it is substantially lower, perhaps because the fabric is dark navy blue. For the higher heat flux level, heat flux resistance is about 50 seconds, and the fabric chars in the radiative mode. The slopes of the lines beyond the second-degree burn line are similar to those of the Nomex fabric.

It should be again emphasized that the "heat flux resistance" as the phrase is used here is essentially a comparative measure, and actual times to burn could vary widely from them, depending on physiological and physical factors during the exposure. Also, the results apply only to the fabrics tested and cannot be generally applied to other fabrics of similar fiber content, construction, or treatment nor to other test conditions. The following discussion should be considered with this in mind.

The heat flux resistance for 14 fabrics which passed the screening for self-extinguishment and which were used in improved garments are shown in Figures 9A-E. The fabrics are arranged in order of increasing weight. Fibers represented are FR polyester, wool, and rayon; FR treated wool/polyester, FR polyester/FR rayon blends; and Nomex and a Nomex/Kynol blend. Data for typical commercial vinyl boot material are also shown. The following is indicated by the data:

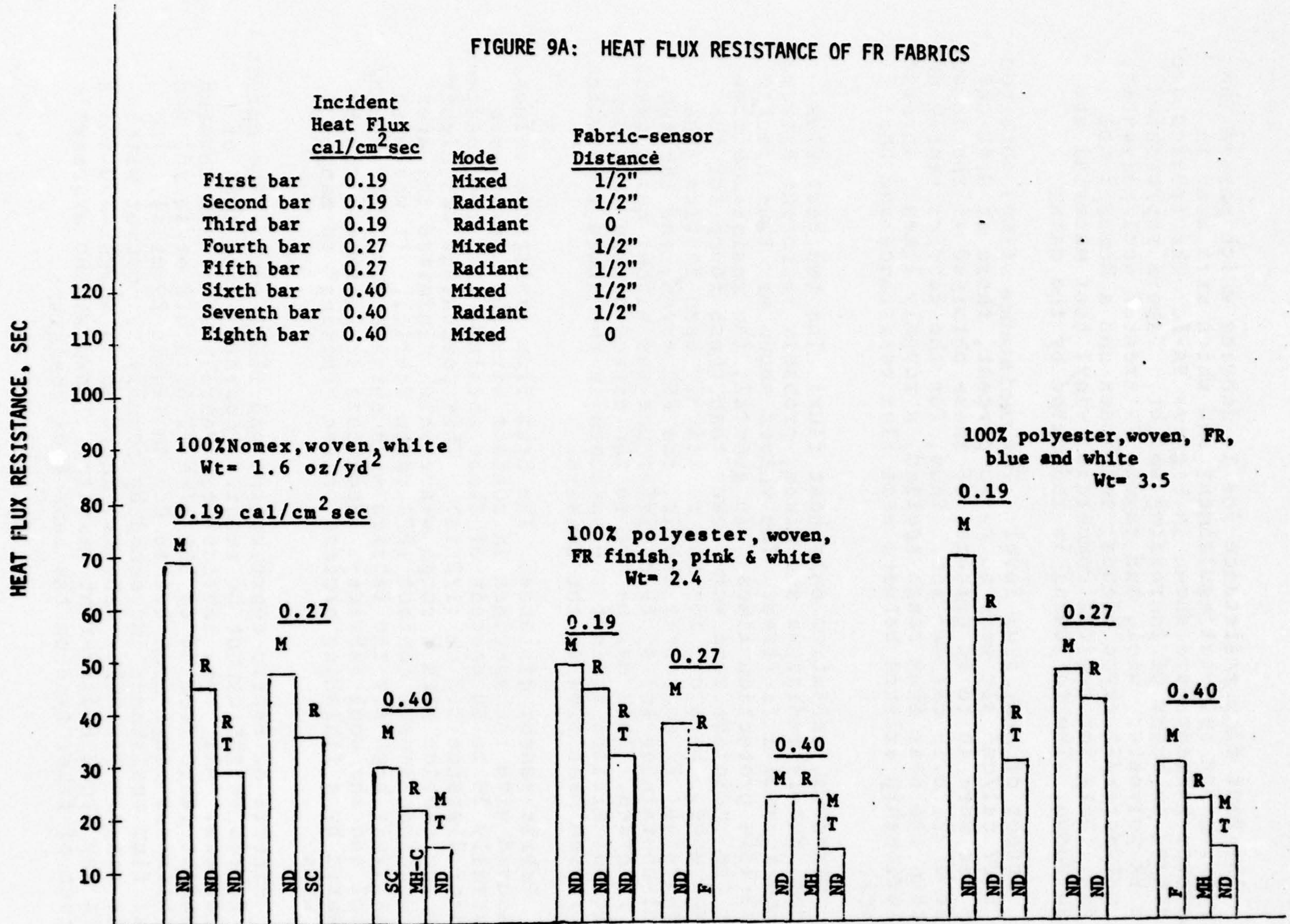
Effect of heat flux level: The resistance times obtained at 0.27 cal/cm^2 sec were 60 to 80 percent, those at 0.40 cal/cm^2 sec were 40 to 60 percent, of those obtained at the lowest heat flux, 0.19 cal/cm^2 sec. Thus, for the fabrics tested and within the heat flux range applied, a roughly linear, inverse relationship existed between heat flux resistance and heat flux level.

Mixed vs. radiative only heat flux: The two heat flux modes, purely radiative and mixed, probably represent extremes found in real-life fires. The values shown may thus bracket real-life protection times. In general, the resistance times for the radiative mode were lower than those found for the mixed mode. However, for the relatively open fabrics (the lightweight FR polyester fabric, the PFR rayon, and the two wool-containing knits) this difference was either quite small or reversed. This may be due to the effect of the considerable hot airflow against the specimen in the mixed mode which increased heat flow to the sensors.

Fabric-sensor distance: The heat flux resistance values measured with the specimen in contact with the sensor were generally 30 to 50 percent of those obtained with the specimen-sensor distance 1.3 cm (1/2 in). This percentage was higher for the fabrics with a rough weave which minimized the area of specimen-sensor contact (PFR rayon fabric). It was also relatively high for the fabrics with surface fuzz (the Nomex/Kynol and the wool fabrics). Such fuzz or hairiness can be created by a finishing process called "raising" on many fabrics.

Effects of fabric construction and fiber type: The effect of fabric weight cannot be readily separated from that of thickness. All Nomex fabrics were densely woven and covered a weight range from 54 to 231 g/m^2 (1.6 to 6.8 oz/sq yd) and a thickness range from 0.4 to 0.7 mm (14 to 29 mils). The heat flux resistance increased by roughly 50 percent within this range. For other fabrics, increase in weight and thickness may produce different results. There was no systematic effect of fiber type on the heat flux resistance.

FIGURE 9A: HEAT FLUX RESISTANCE OF FR FABRICS



For Mixed Mode: At 0.19 cal/cm^2sec: 40% convective/ 60% radiative
At 0.27 cal/cm^2sec: 30% convective/ 70% radiative
At 0.40 cal/cm^2sec: 20% convective/ 80% radiative

ND - No Damage
MH - Melt Holes
SC - Slight Char
VC - Very Charred

C - Char
M - Mixed
R - Radiative
T - Touching
F - Fused

FIGURE 9B: HEAT FLUX RESISTANCE OF FR FABRICS

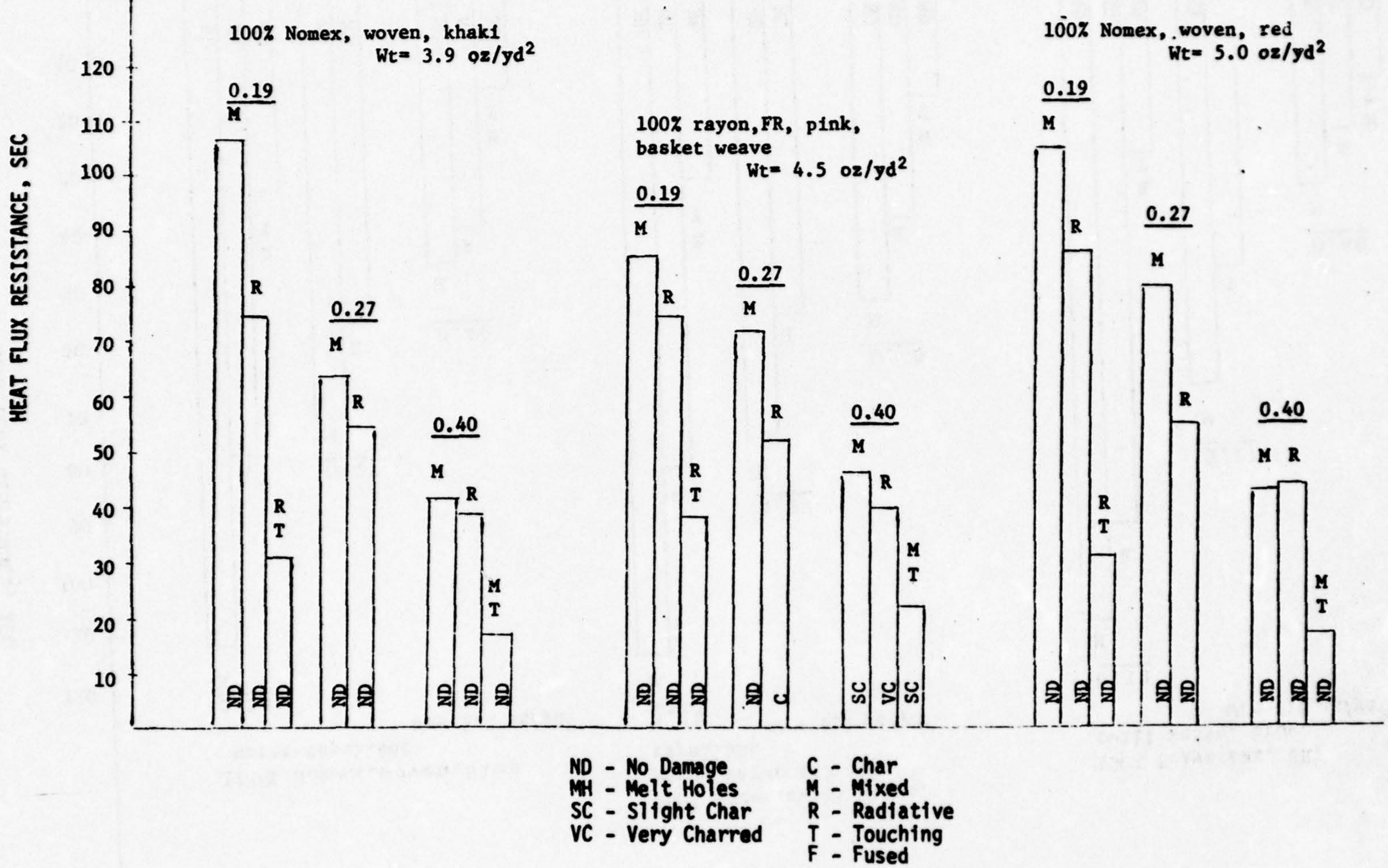


FIGURE 9C: HEAT FLUX RESISTANCE OF FR FABRICS

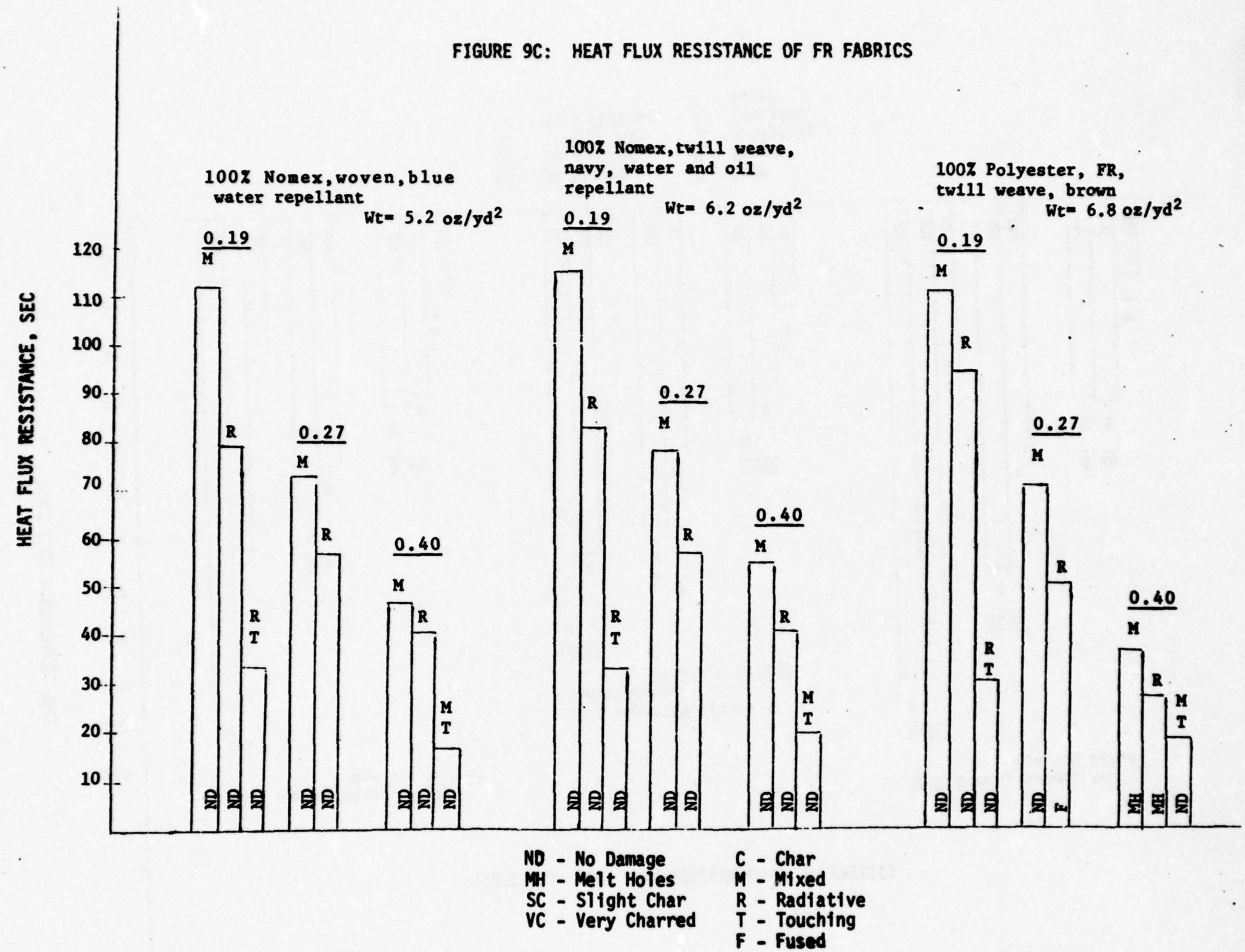


FIGURE 9D: HEAT FLUX RESISTANCE OF FR FABRICS

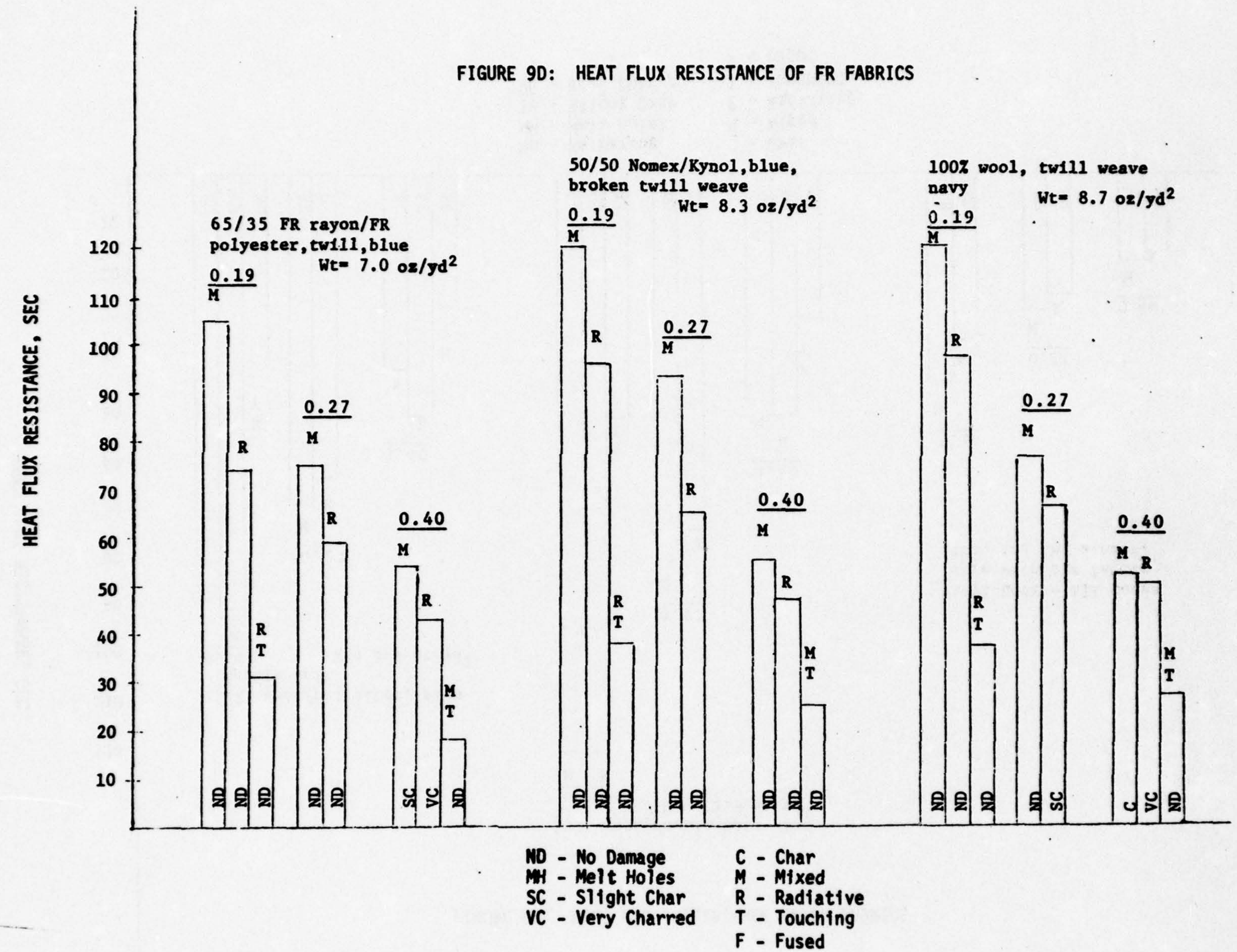
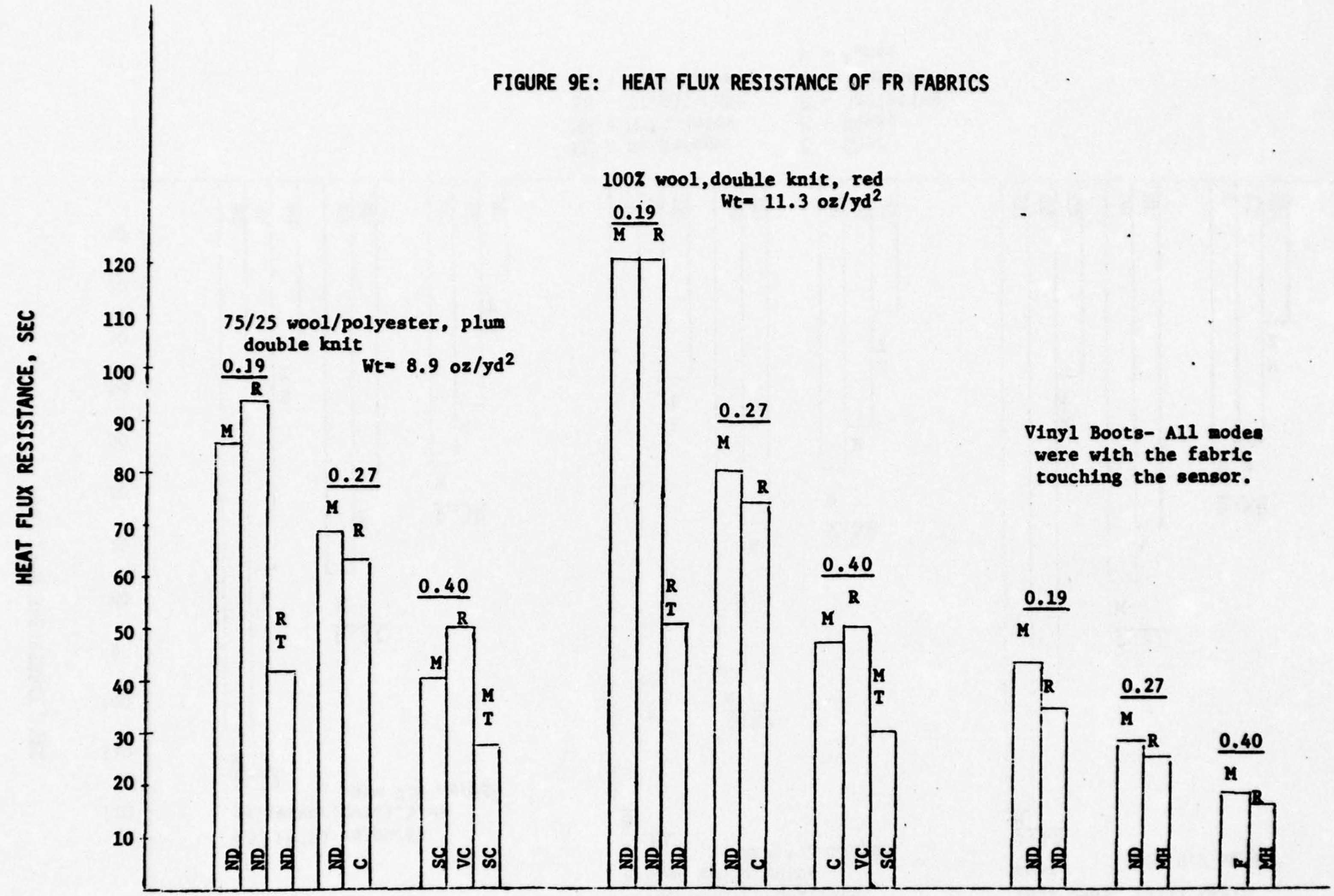


FIGURE 9E: HEAT FLUX RESISTANCE OF FR FABRICS



ND - No Damage
MH - Melt Holes
SC - Slight Char
VC - Very Charred

C - Char
M - Mixed
R - Radiative
T - Touching
F - Fused

However, the resistance to disintegration of the fabric, by formation of melt holes or chars, clearly depended on the fiber type and fabric weight. Occurrence of melting or charring is indicated at the bottom of each bar in the figures. Thus, the lightest Nomex fabric showed slight chars at 0.27 cal/cm^2 sec radiative heat flux and holes at 0.40 cal/cm^2 sec. None of the other Nomex fabrics showed any damage. Wool fabrics started charring at 0.27 cal/cm^2 sec radiative. The FR polyester started fusing at the same heat flux level, and melt holes formed at 0.40 cal/cm^2 sec. The fusing indicates softening of the material, which in real-life could increase the garment contact with the skin, possible sticking to the skin, and intensified heat transfer and injury levels.

The three experimental fabrics, the PFR rayon, the PFR rayon/Dacron 900F (FR polyester) blend, and the Kynol/Nomex fabrics, exhibited heat flux resistance values which can be explained by their weight and density. The PFR rayon started charring at the 0.27 cal/cm^2 sec radiative heat flux and PFR rayon/Dacron 900F blend at 0.40 cal/cm^2 sec, both mixed and radiative. The Kynol/Nomex blend neither charred nor fused. Unfortunately, this blend is only in pilot production and would have serious deficiences of appearance and perhaps durability in F/A uniforms.

The last set of bars shows the results obtained with commercial vinyl boot material. These results were obtained with the specimen in contact with the sensor, to simulate the usual tight fit of such boots. Heat flux resistance under those conditions do not seem to be unreasonable, but the material formed melt-holes at 0.27 cal/cm^2 sec.

Ignition while the specimens are exposed to heat flux was not part of the original experimental plan. The apparatus is, however, equipped to perform such experiments. Specimens of a polyester, a Nomex, and a wool fabric were exposed to a 2 cm (3/4 in) methane flame after 1 minute exposure to radiative heat flux at the 0.19 cal/cm^2 sec level. The polyester melted, but did not burn. The Nomex charred only slightly, even after 9 seconds exposure to the flame. The wool charred after this exposure over a larger area but self-extinguished. These results suggest that wool and Nomex possess self-extinguishing characteristics under more critical conditions than generally considered in this work.

2.4.2.4 Choice of Conditions for Heat Flux Resistance Test of Proposed Standard

The results of the above experimental investigations indicated that the test procedure could be simplified for the purposes of the proposed standard. The simplification involves several changes--use of radiative heat flux only; use of a flat, rather than a semicircular, specimen; and use of a commercial total heat flux sensor.

Figures 9A-E show that, in general, the radiative heat flux mode is more severe than the mixed mode. In the few cases where a lower heat flux resistance was obtained for the mixed mode, the differences were quite small. Since the mixed mode requires considerably more equipment and would add little information of importance to the F/A's safety, it was eliminated from the proposed standard.

On the other hand, the results showed that the specimens be tested both in contact with the sensor and at some distance from it. These conditions simulate the free-hanging and the tight-fitting garment conditions. The results in the free-hanging mode are mostly affected by fabric density, color, and thickness, while those obtained in contact are also affected by surface roughness and hairiness of the fabric. The proposed standard requires testing in both modes.

Figures 10 and 11 compare the results obtained when the fabrics were tested on the curved specimen holder described above under 2.4.2.2 and on the much simpler, flat specimen holder recommended for the proposed standard and shown in Figure 3, Appendix C. Considering the variability of fabrics, the agreement between the results is fair. The pass-fail criteria for the proposed standard were based on the measurements made with the much simpler flat sensor. Few fabrics which passed with this sensor would fail with the curved sensor, and vice versa. The pass-fail criteria were chosen to obtain the highest level of insulation compatible with ready availability of fabrics which qualify and which would also be acceptable from other points of view (2.3).

Exposure at 0.40 cal/cm^2 sec was made a requirement in the proposed standard because melting of fabrics can be observed at this test condition. A test for melt behavior was required by the Interagency Agreement; the reasons for it are discussed in detail in 2.2. Basically, heat shrinkage and softening previous to melting reduce the insulating characteristics of fabrics, and melting destroys their integrity and ability to protect. Charring also can be observed at

FIGURE 10: COMPARISON OF HEAT FLUX RESISTANCE RESULTS FOR THE FLAT AND CURVED SENSORS

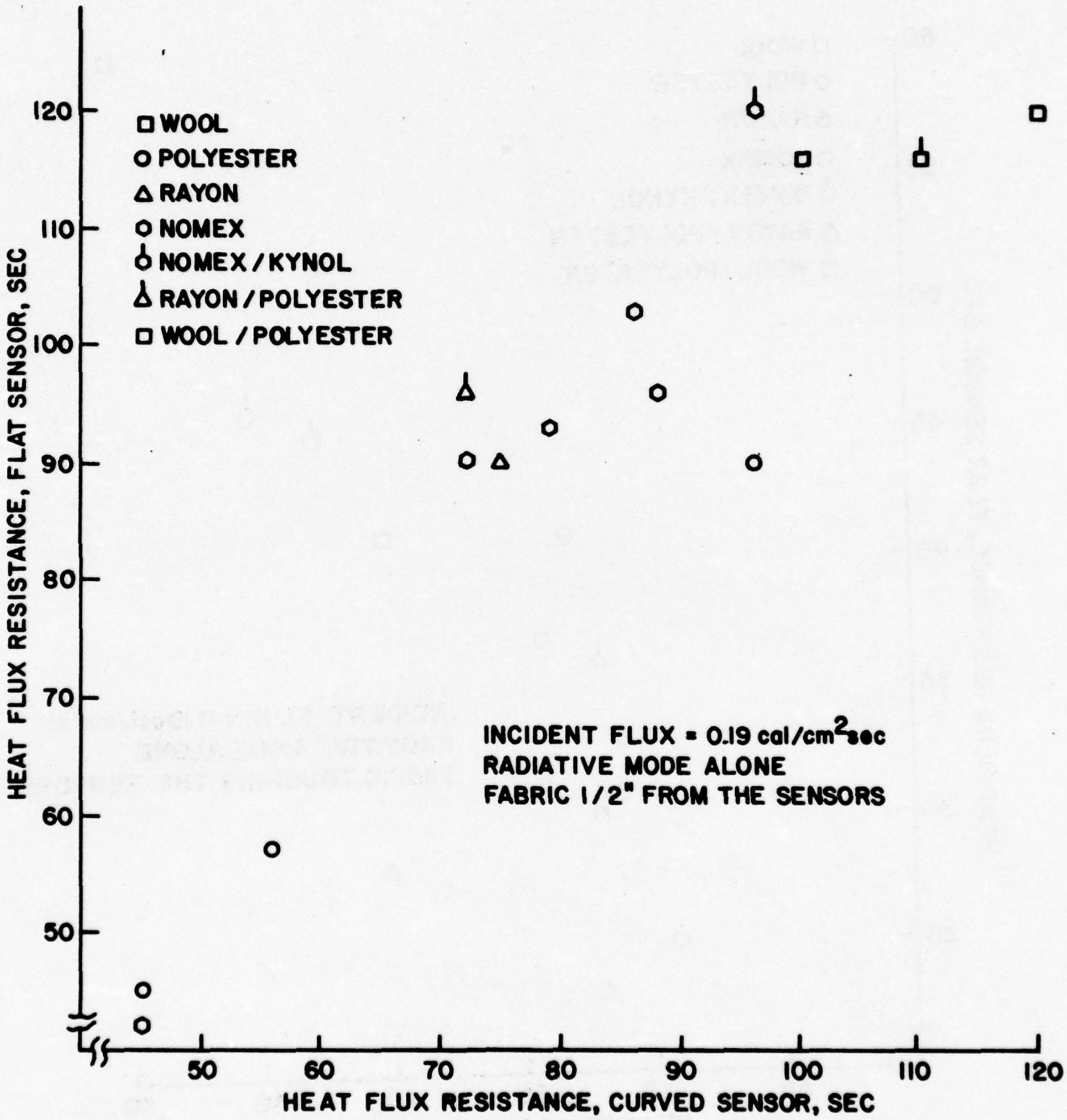
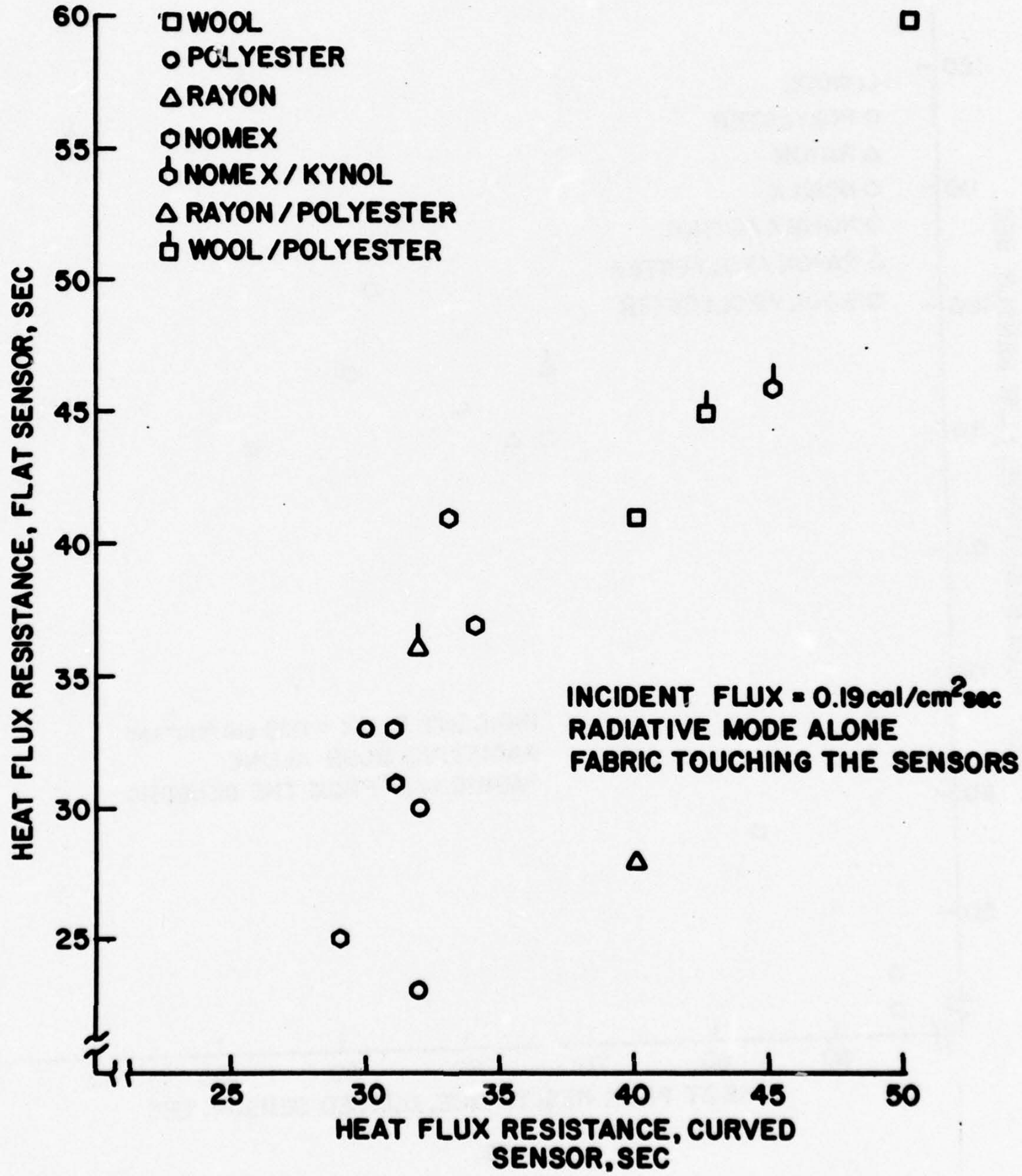


FIGURE 11: COMPARISON OF HEAT FLUX RESISTANCE RESULTS FOR THE FLAT AND CURVED SENSORS



0.40 cal/cm^2 sec heat flux. If chars are brittle, they may loose their integrity. The proposed standard includes a provision to determine brittleness of chars (4.2.5.2, Appendix C).

The proposed standard covers double layers of fabric where the second layer is an integral part of the garment, such as linings. It does not address underwear for several reasons. First, there are many garments which are worn without underwear, and only the protective characteristics of the outer-garment affect the hazard in such cases. An outer-garment which has high protective value will, of course, prevent the underwear from shrinking, melting, or igniting. The choice of underwear is not controlled by the airlines. Finally, though it could be expected that FR underwear may be safer, its price and, at least at present in many cases, the comfort characteristics would probably be unacceptable.

2.5 Mannequin Burns of Prototype Uniforms Made From FR Fabrics to Achieve Improved Fire Safety

These tests are described in Appendix B. This work consisted of mannequin burns of F/A uniforms made up from present-day commercial and experimental FR fabrics. The purpose was two-fold: to demonstrate the feasibility of constructing uniforms with improved fire safety and to provide an additional screening of fabrics which were found to be self-extinguishing in laboratory testing when incorporated in a garment. It is emphasized that not all of these fabrics conform with the pass-fail criteria for protection against radiative heat flux, selected for the proposed standard in Appendix C. The term "improved" thus refers primarily to the self-extinguishing features of the fabrics and uniforms, not to overall fire protective characteristics which also considers radiative heat resistance.

The fabrics were chosen because they passed the FF 5-74 tests and because they were reasonably similar to the fabrics presently used in F/A uniforms in appearance and feel. The FR treated polyester fabrics were chosen because they passed the FF 5-74 test and because they are widely used in applications where self-extinguishment is required, such as children's sleepwear. Their shortcomings are discussed in Appendix B.

Fourteen fabrics were selected. They are the fabrics characterized in Figures 9A-E. They include 100 percent polyester, Nomex, rayon, and wool and blends of polyester and wool, rayon

and polyester, and Nomex and Kynol. Uniform items included: blouses, skirts, tunic/slack combination, uniform jackets, blazer, overcoat, raincoat, serving apron, and muumuu. The skirt configuration was considered most critical for testing because of an ample air supply on both sides of the fabric.

The cutting and sewing of the uniforms was performed in the pilot sewing facility of a major career apparel manufacturer. They resemble F/A uniform items used in the 1974-75 season as closely as possible. The uniforms were ignited on mannequins as described under 2.1. The burn tests were filmed and video-taped. Details are given in Appendix B.

Since all of the fabrics passed the self-extinguishment test, the "improved" uniforms did not burn significantly beyond the area of the igniting paper towel. One exception was a 100 percent FR polyester skirt which burned downward to the hem. No significant heat transfer to the mannequins was recorded during the burns, except in the area of the ignition source. Consequently, no figures showing potentially burned skin areas are included. Exceptions were polyester blouses which formed holes in the area of the ignition sources and thus did not protect the bras under them from igniting and burning. This did not occur when the blouse was made from Nomex. The mannequin burns of the polyester blouses thus demonstrated one of the disadvantages of materials which melt in contact with or near flames.

3. CONCLUSIONS

The tests and data described in this report support the provision of the proposed flammability standard for flight attendant uniforms, which is attached, as Appendix C. It indicates the feasibility of significant improvements of the fire safety of F/A uniforms, over that of the currently used uniforms. This can be done by providing both better protection against ignition and against heat flux in the early stages of a cabin fire.

Specific conclusions are listed below:

3.1 The flammability of many presently used uniforms was tested during mannequin burns and found to be unsatisfactory in some, but not all cases. However, many of the fabrics which burned tenuously and self-extinguished shrank, softened, and melted.

3.2 A number of self-extinguishing fabrics which also have reasonable insulation characteristics and are suitable as substitutes for presently used fabrics are available for use in uniforms with improved fire safety.

3.3 The appearance, ease of care, and cost of such uniforms may not equal that of presently used garments.

3.4 Injury potential depicted by mannequin burn tests are only an approximation of actual conditions because of limitations of instrumentation and because the static conditions on the mannequin cannot predict defensive action by the wearer of the burning garment, such as doffing the garment, rolling on the floor, etc.

3.5 Underwear, stockings, boots, wigs, and other apparel available on the market and worn by F/As but not controlled by fire safety specifications could affect the extent of burn injury.

3.6 The "heat flux resistance" in terms of the time until a given radiant flux penetrates fabrics sufficiently to cause a second-degree burn on skin, appears to be a feasible method to rank fabrics for protective ability. Fabrics can thus be qualified for a given resistance to heat flux in terms of exposure time until second-degree burn may occur.

4. REFERENCES

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5. APPENDIX A

Mannequin Burns of Presently Used Uniforms

This appendix presents data obtained from mannequin burns of 14 F/A uniforms and components in 1974-75 use.

Section I reports mannequin burns conducted at NBS; Section II those conducted at Gillette Research Institute.

Each garment combination consisted of a uniform assembly, underwear, hose, wig, etc. The garments were always ignited in an area where they were at some distance from the size 10, female mannequin (garments often do not ignite when in contact with a mannequin). Usually the first ignition was on the side, at about knee level. If garments self-extinguished or burned tenuously and were easily extinguished (many garments performed in this manner), they were ignited again at such locations as the chest, sleeve, or back of the shoulder.

Each individual burn is reported by schematic representation of the potential injury. This is accomplished by showing on a drawing of the mannequin (a) the area of the outside garment which burned at a given time from ignition and (b) the heat received by the 24 sensors on the mannequin surface. The outside burn is indicated by shading of the area on the schematic drawing. The heat received by the sensors is indicated by various symbols superimposed on the point indicating sensor location. If the sensor received less than 2.0 cal/cm^2 sec, no symbol is superimposed on this point, indicating that no burn injury could be expected to have occurred in a real-life fire. (As explained in the report, 2.0 cal/cm^2 sec is a conservative estimate of the heat flux necessary to inflict a second-degree burn. Higher heat flux causes deeper burns.)

In addition, each schematic drawing shows the type of uniform (muumuu, slack suit, etc.), the point of ignition, and the number of the burn. Schematic drawings were prepared to show the progress of the fires and injury pattern 15, 30, 45, 60, 75, and 90 seconds after ignition. Wherever a schematic drawing is missing for any one time from ignition and burn test, heat transfer had either not started or was not changed from the previous time. In addition, a short description of the occurrences during the burn is given.

To expedite this investigation, some burn tests were conducted at the Gillette Research Institute on their mannequin

system under an agreement with FAA and NBS. Their system of data acquisition cannot be readily converted to the schematic presentation discussed above. However, their data and observations are included as Section II in this Appendix. Although the detailed test procedures and data presentation by Gillette Research Institute are not exactly the same as that used by NBS, the results are capable of providing base line criteria needed to assess the hazard of currently used F/A uniforms which is the essential purpose of this phase of the project.

The following F/A uniform items were burned:

<u>Burn No.</u>

1 (GRI 341-2) *100% Polyester Double-Knit Blazer and Skirt, 100% Nylon Blouse, 100% Polyester Scarf, Wet-Look Shoes

2 100% Polyester Muumuu

3 100% Polyester Pants, Vest, and Scarf; 100% Nylon Blouse

4 100% Acrylic Pants and Tunic

5 100% Polyester Skirt and Blouse

6 75/25% Polyester Wool Skirt and Jacket, 100% P.E. Body Suit, burned also with 100% Wool Coat and with 50/50% P.E./Cotton Apron

7 100% P.E. Pants, Blouse, Serving Smock

8 65/35% Wool/Polyester Jumper, 100% P.E. Body Suit, 50/50% P.E./Cotton Apron

9 100% Wool Topcoat, Nomex and Rayon Linings

10 (GRI 341-5) *55/45% Polyester/Wool Male Suit (Coat and Trousers)

*65/35% Polyester/Cotton Raincoat, 100% Alpaca Backing, 51/49% Rayon/Cotton Sleeves; also burned without lining at NBS

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* Tested by Gillette Research Institute under contract to NBS.

11 (GRI 341-4) *100% Polyester Muumuu

12 (GRI 341-6) *65/35% Wool/Polyester Skirt and Jacket, 100% Polyester Body Suit

13 100% Polyester Skirt, Shorts, Blouse, Smock

14 100% Polyester Jumper and Blouse

In some cases, the uniform assemblies were ignited more than once, without change or with additional garments (like coats) added or taken off. In Section I, this is indicated in the entry for Burn Number on the figures by; e.g., 5-2 (second ignition of assembly 5). The underwear, wig, and shoes were not changed for any one burn number and are listed on the sheet accompanying the figures. The outside garments, such as uniforms, aprons, and coats, are listed on the figures.

Note

Burn injury codes for all NBS mannequin burn tests illustrated in Appendix A, Section I, are shown on Page A-5.

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* Tested by Gillette Research Institute under contract to NBS.

APPENDIX A

Section I. Mannequin Burns Conducted at NBS

BURN #2 - 1, 2, 3

Underwear: Bra - cups, 100% polyester
back and sides, 76/24 nylon/spandex
pad, 100% polyurethane

Panties - 100% cotton

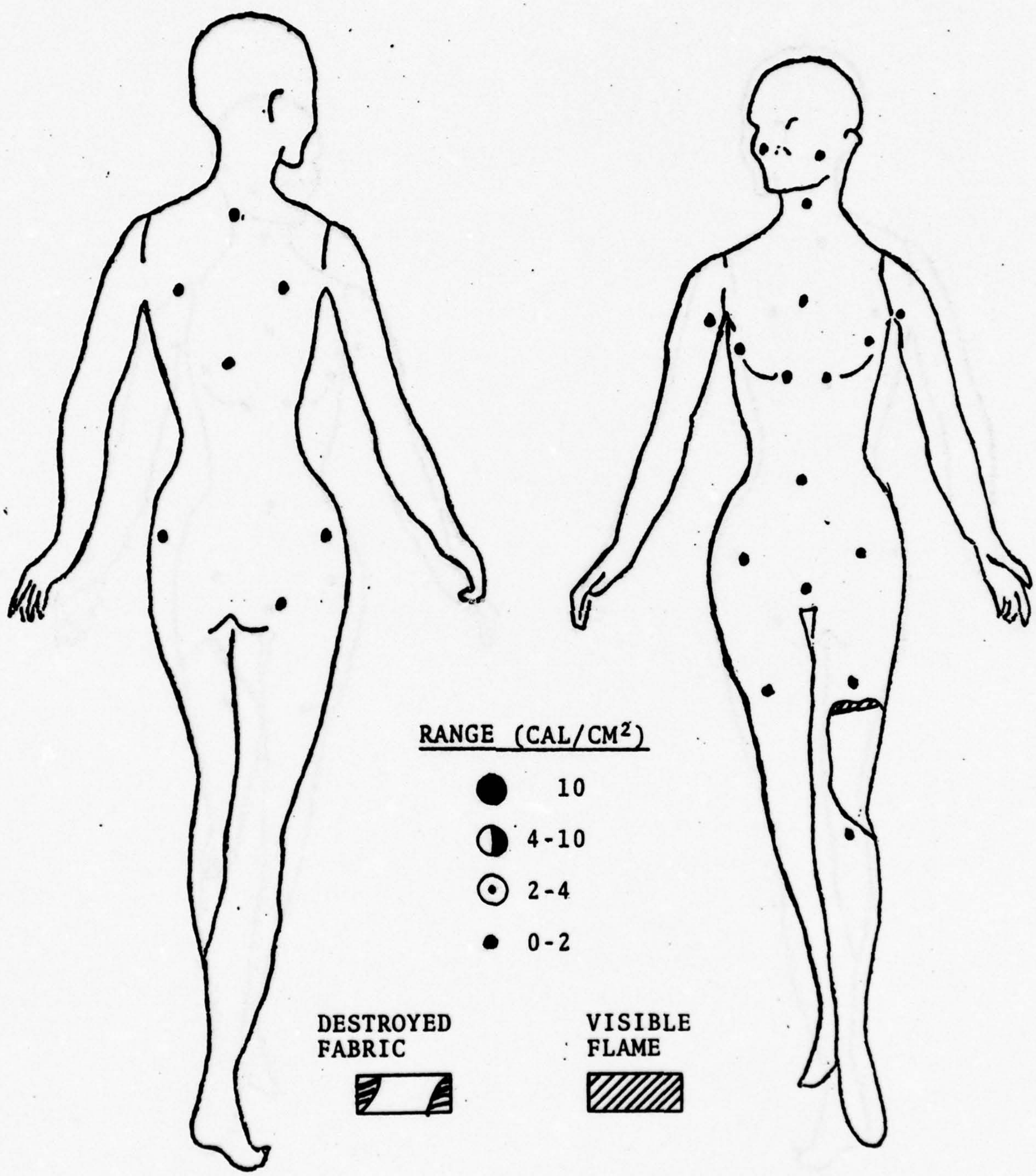
Panty Hose - panty, 80/20 nylon/spandex
stockings, 100% nylon

Wig: Modacrylic

Comments: This clothing system burned tenuously around the edges of melt hole which was caused by the folded paper towel ignition source. There was some melt drip. Flames burned through and melted part of the nylon zipper making it inoperable. There was downward burning.

Three heat sensors registered heat inputs exceeding 2 cal/cm^2, 60 seconds after the third ignition. No heat input was registered in the other burns. (See Figures.)

Heat Input to Mannequin From Burning Flight Attendant Uniforms

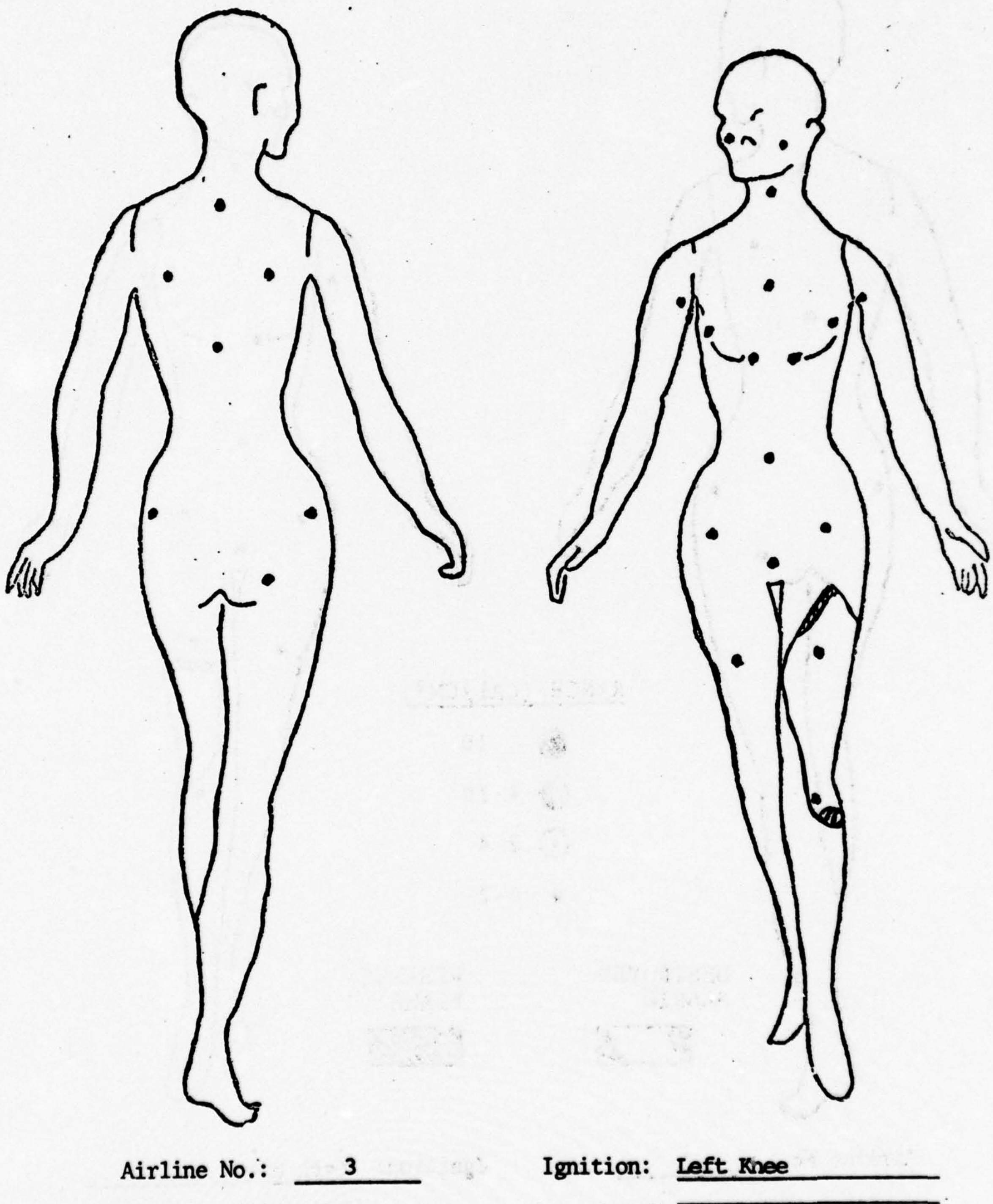


Airline No.: 3 Ignition: Left Knee

Outfit: 100% Polyester Muumuu

Time: 15 seconds Burn I.D. No.: 2-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 3

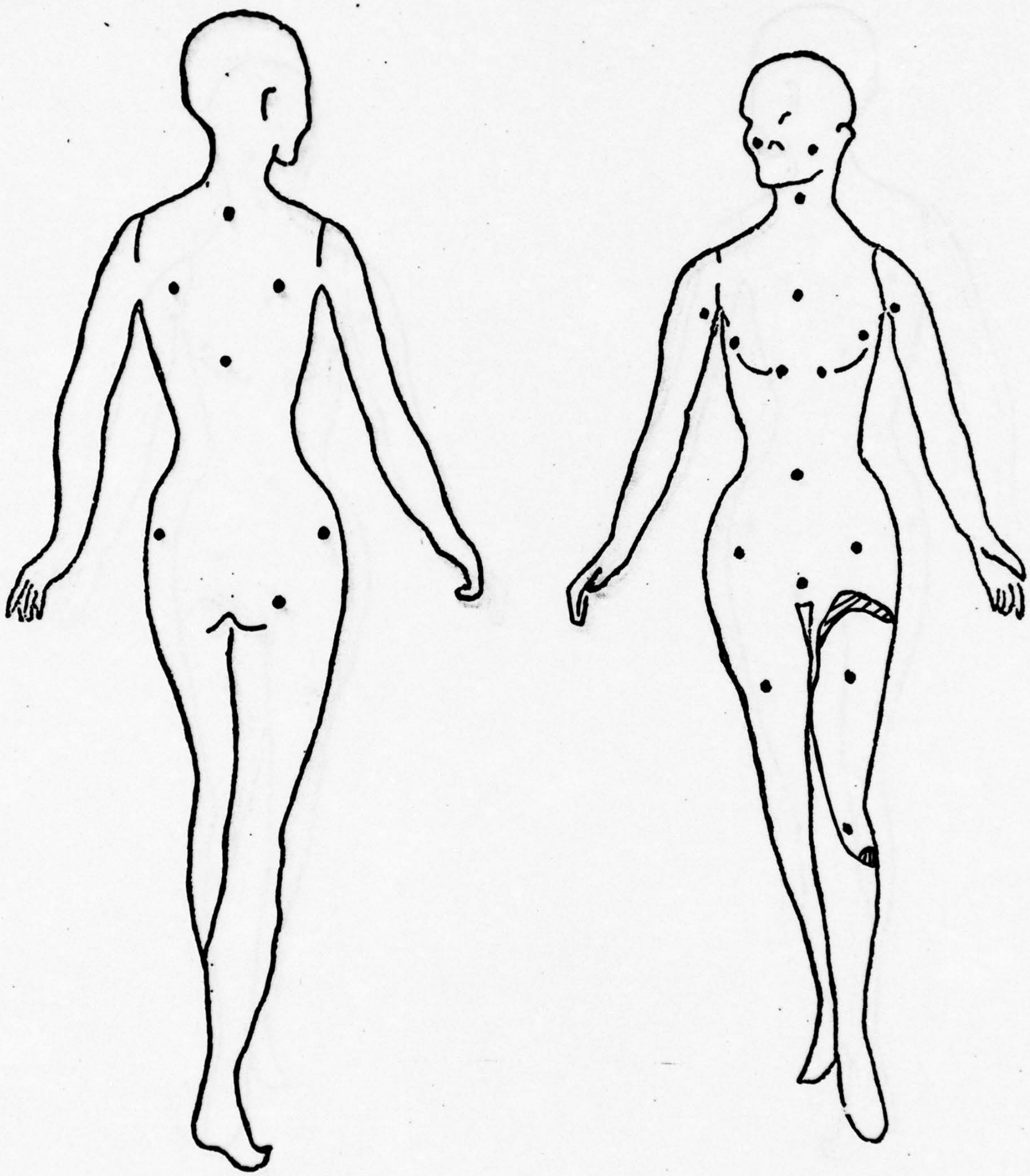
Ignition: Left Knee

Outfit: 100% Polyester Muumuu

Time: 30 seconds

Burn I.D. No.: 2-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

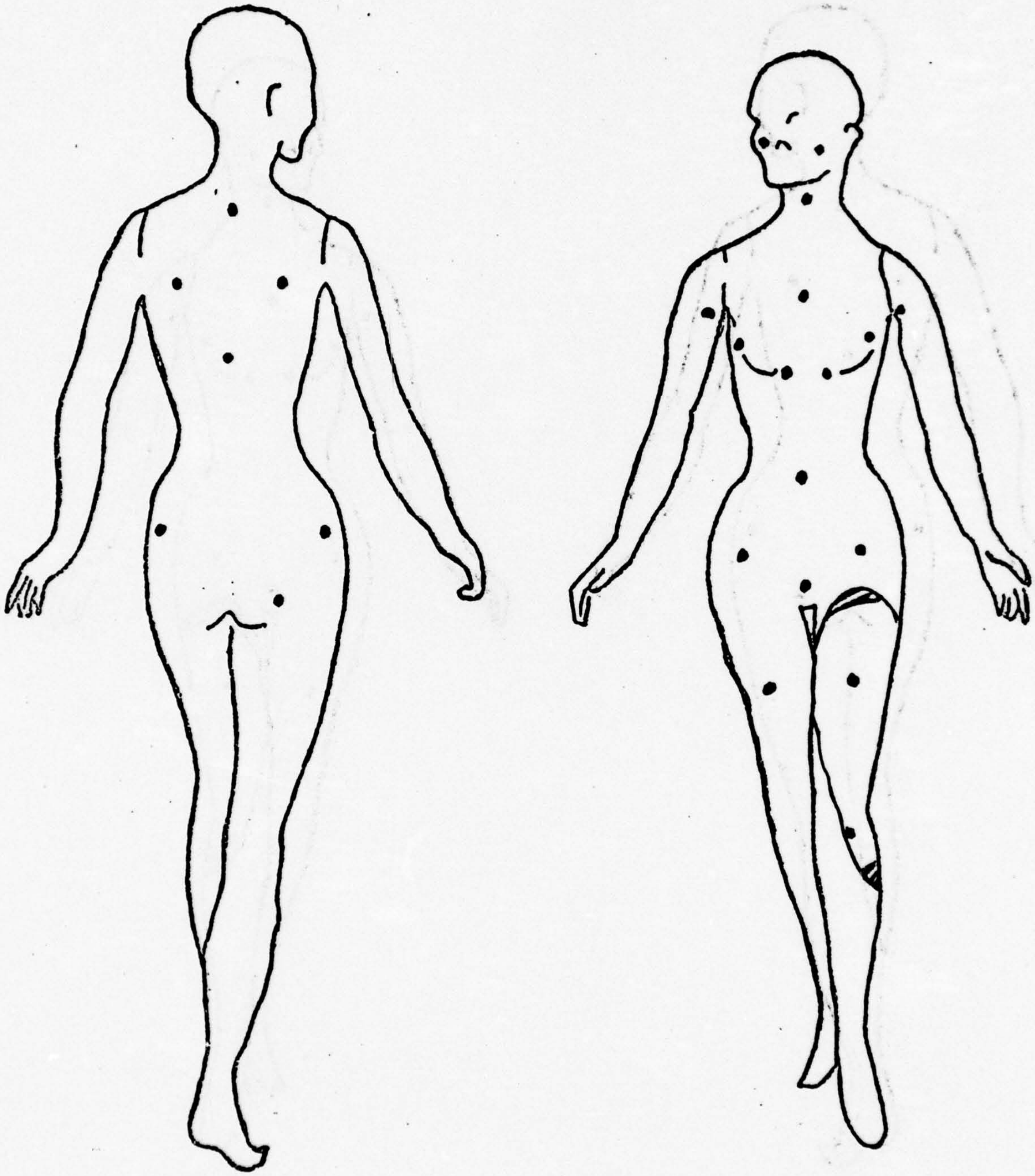


Airline No.: 3 Ignition: Left Knee

Outfit: 100% Polyester Muumuu

Time: 45 seconds Burn I.D. No.: 2-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

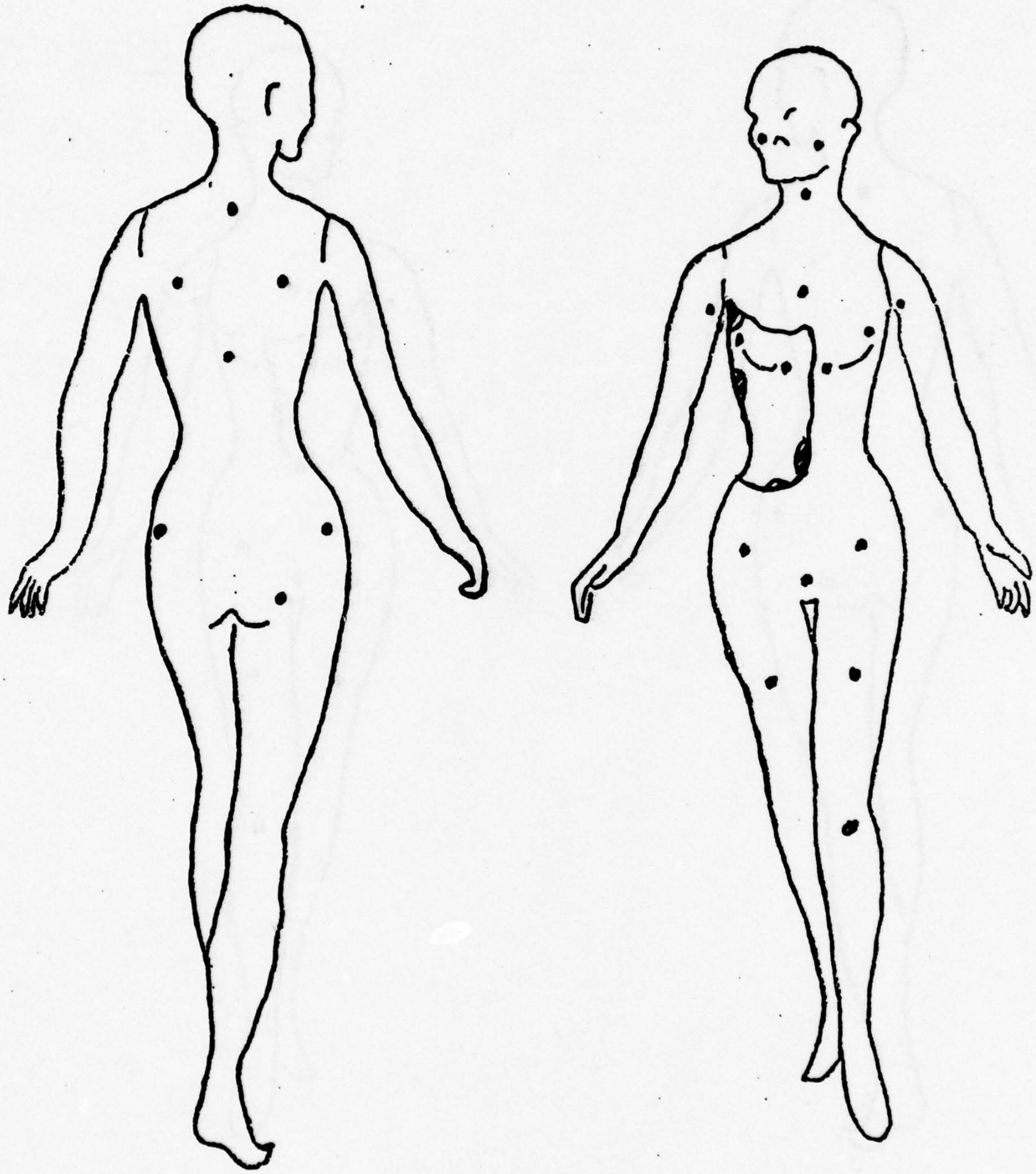


Airline No.: 3 Ignition: Left Knee

Outfit: 100% Polyester Muumuu

Time: 60 seconds Burn I.D. No.: 2-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

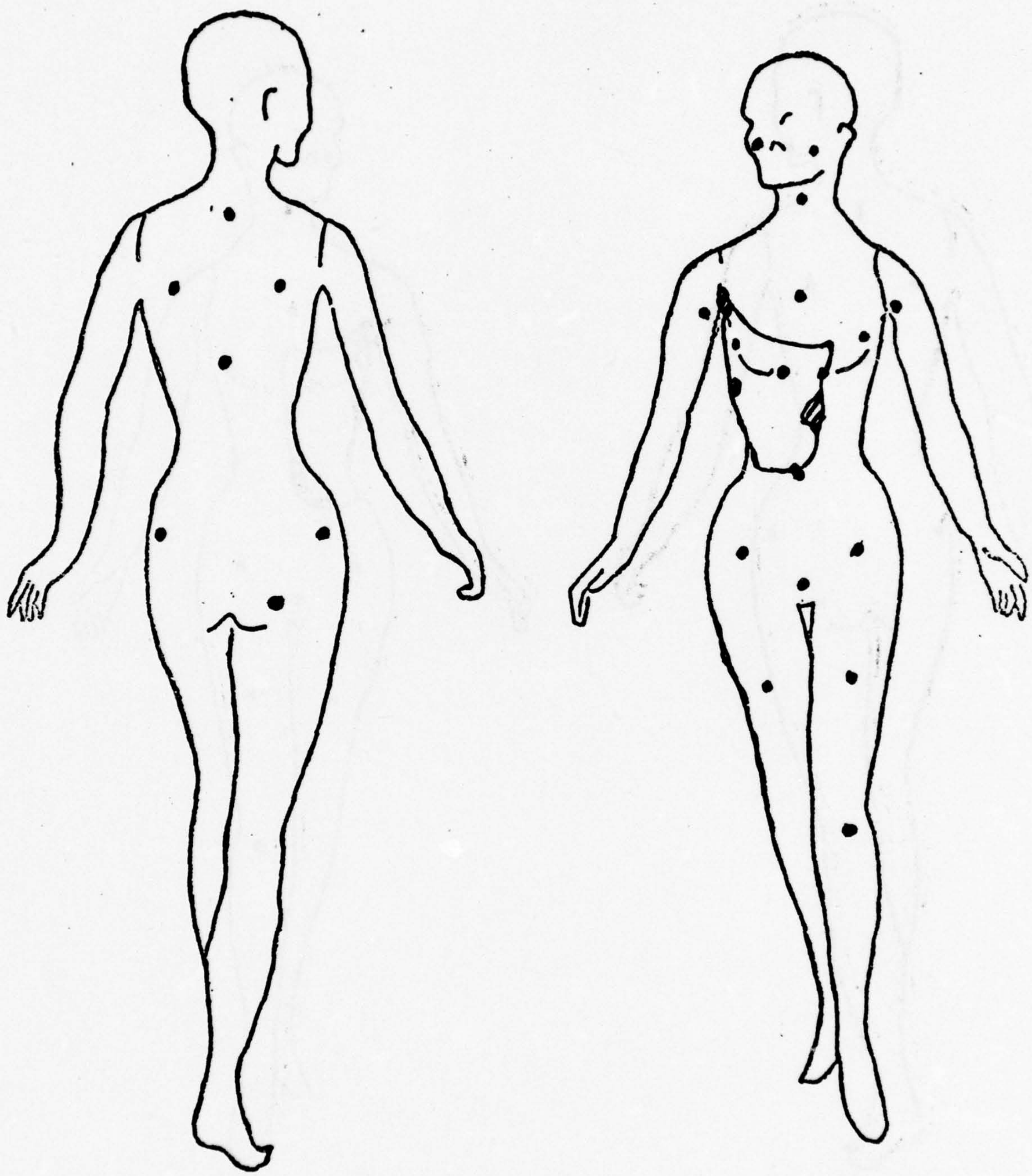


Airline No.: 3 Ignition: Right Chest

Outfit: 100% Polyester Muumuu

Time: 15 seconds Burn I.D. No.: 2-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

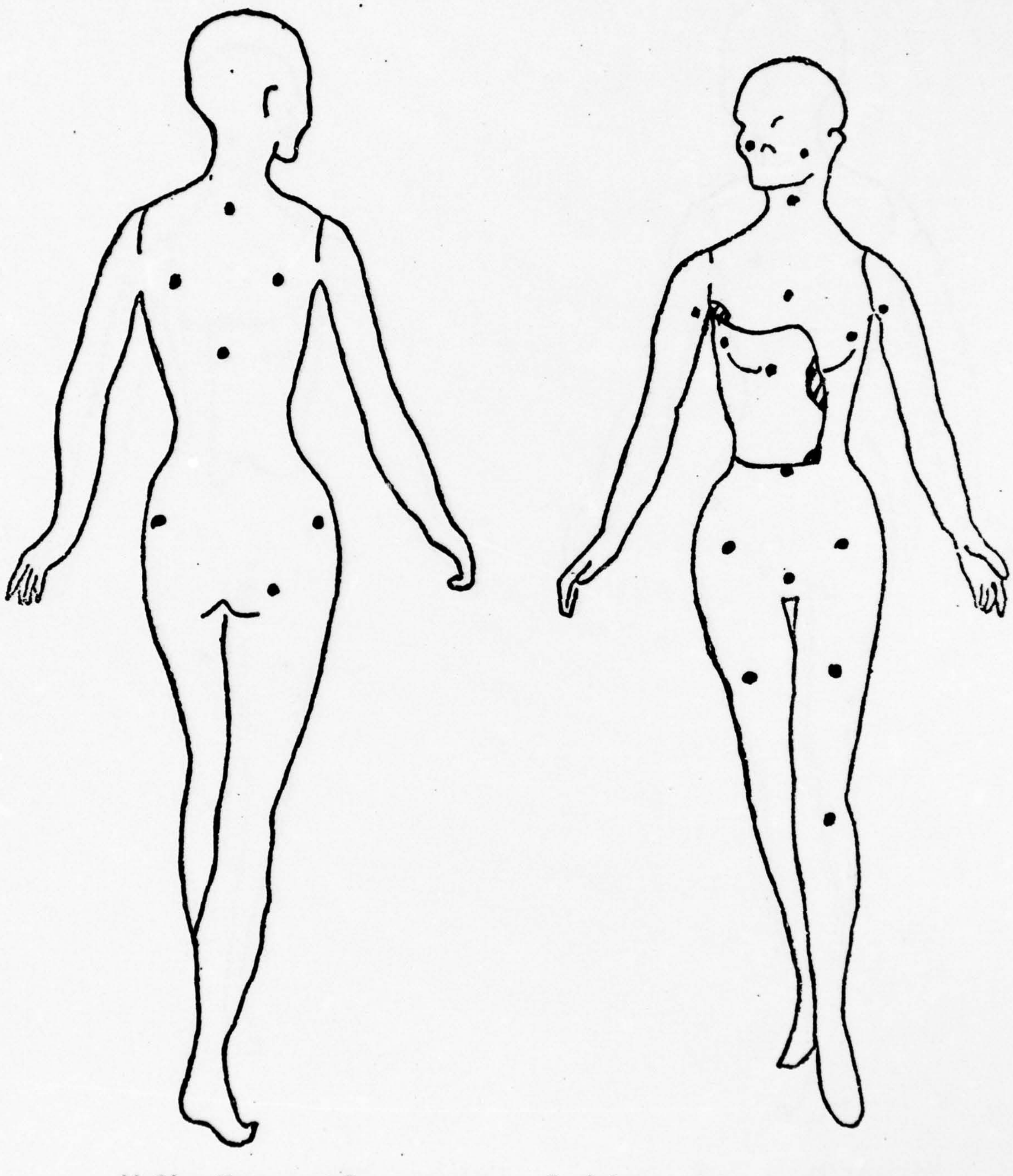


Airline No.: 3 Ignition: Right Chest

Outfit: 100% Polyester Muumuu

Time: 30 seconds Burn I.D. No.: 2-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

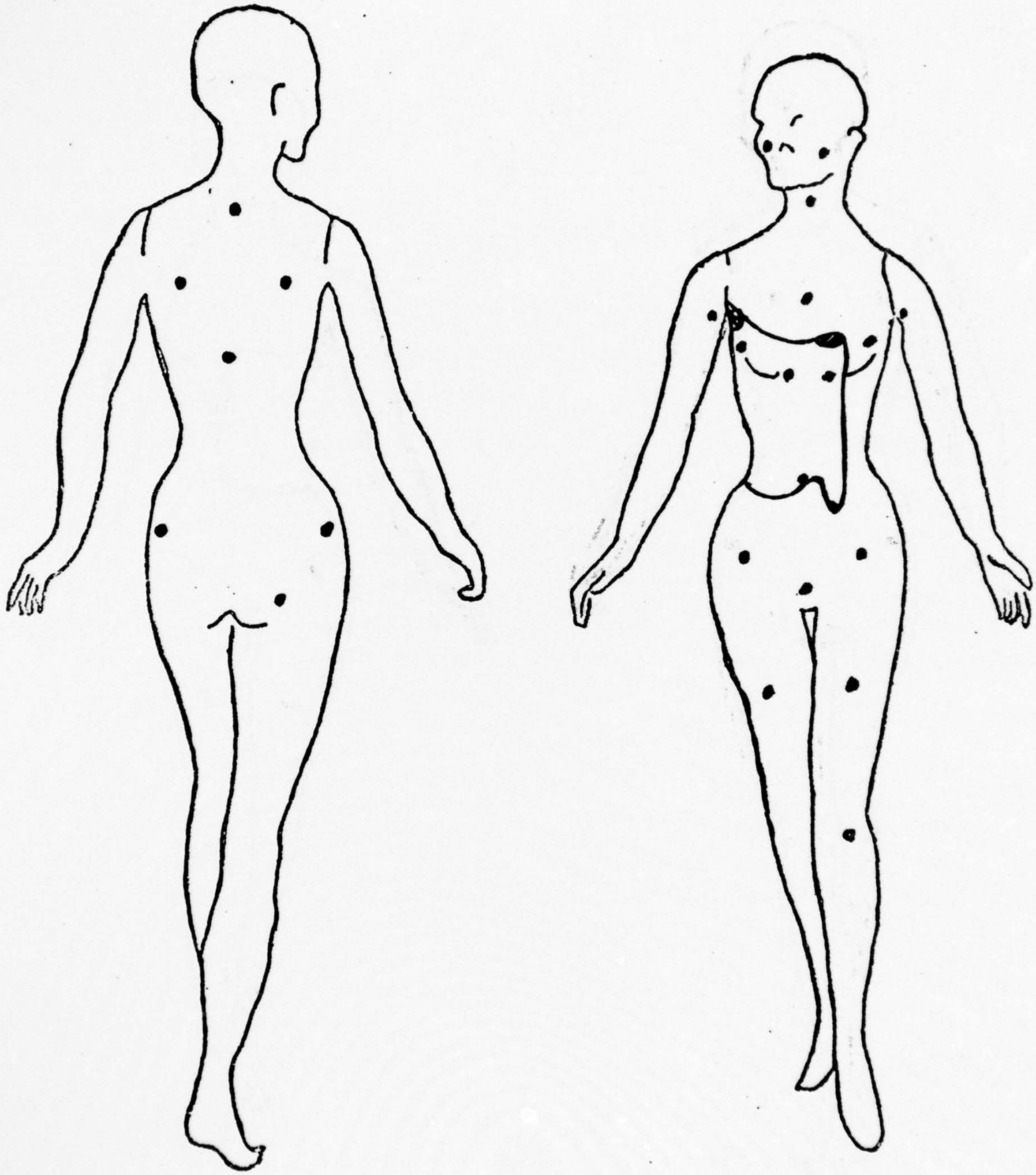


Airline No.: 3 Ignition: Right Chest

Outfit: 100% Polyester Muumuu

Time: 45 seconds Burn I.D. No.: 2-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 3

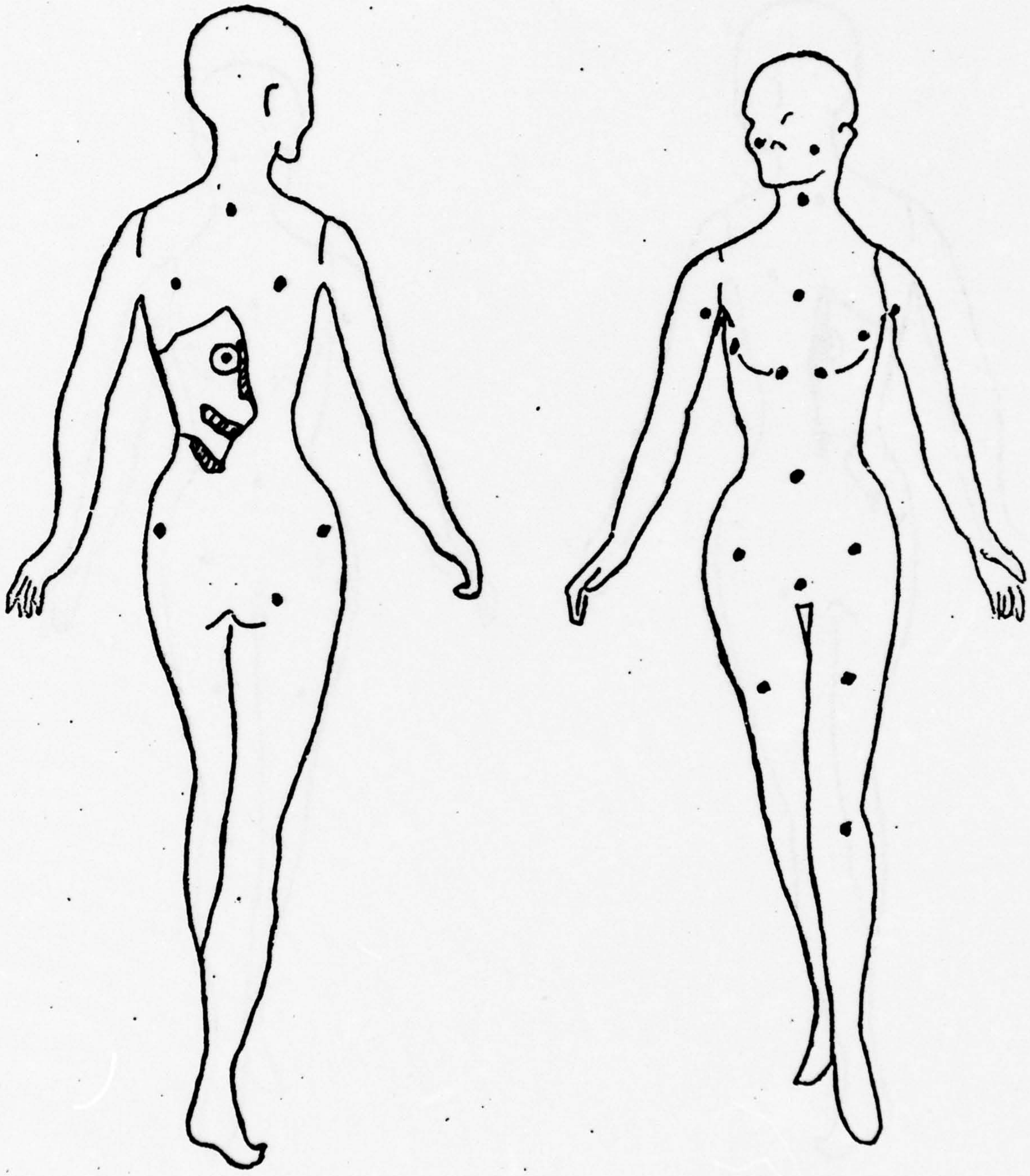
Ignition: Right Chest

Outfit: 100% Polyester Muumuu

Time: 60 seconds

Burn I.D. No.: 2-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

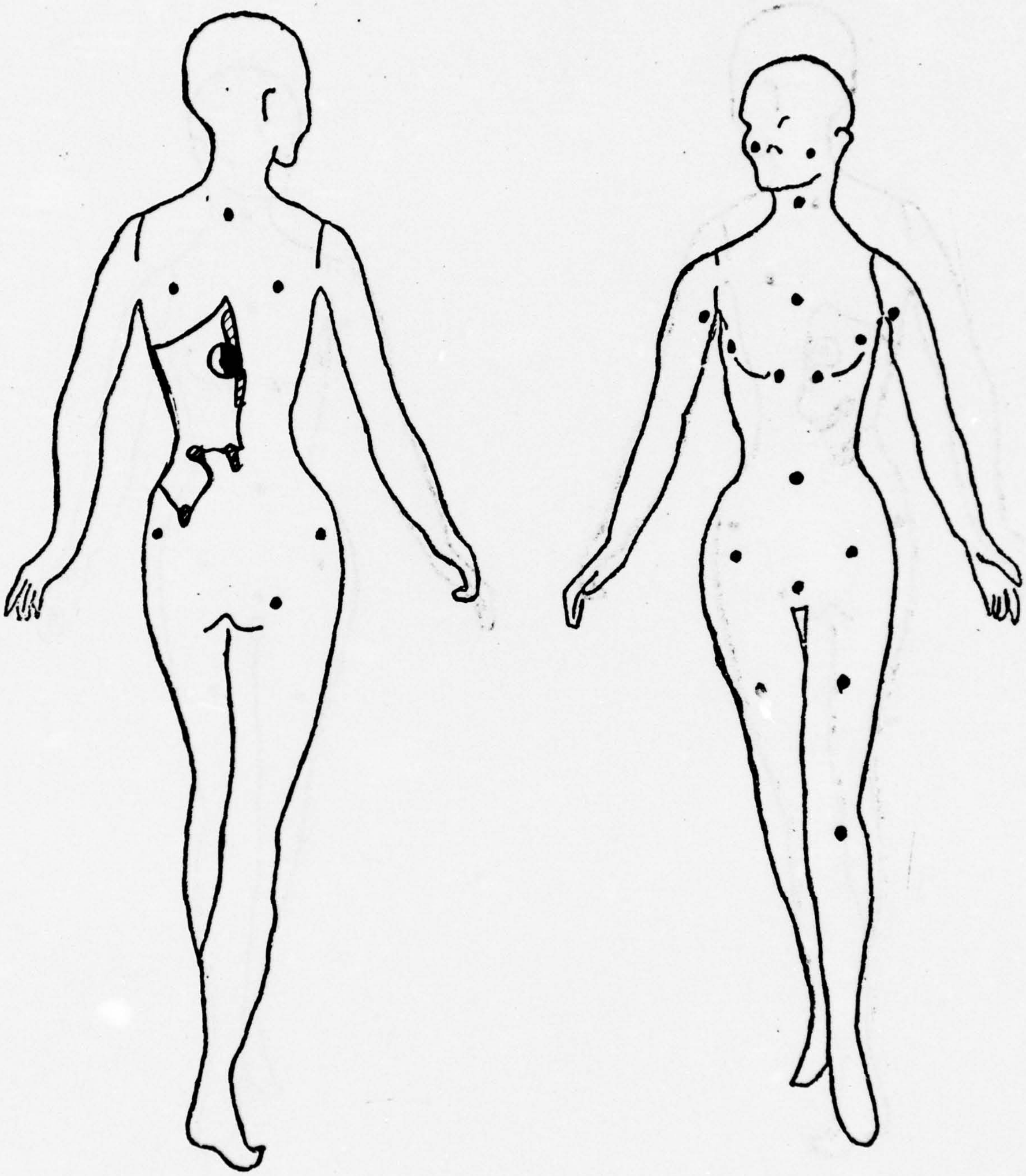


Airline No.: 3 Ignition: Left Back

Outfit: 100% Polyester Muumuu

Time: 15 seconds Burn I.D. No.: 2-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms

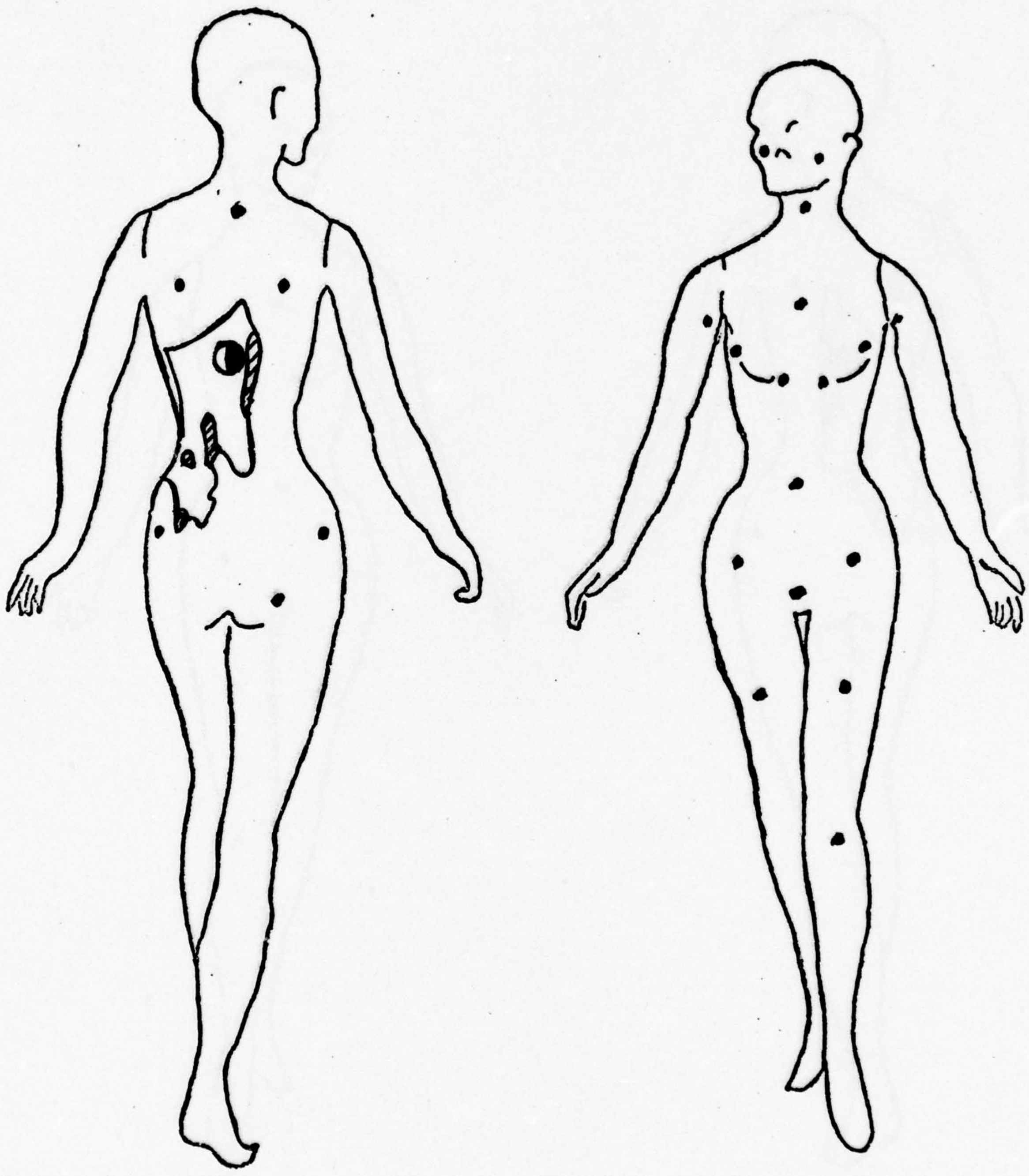


Airline No.: 3 Ignition: Left Back

Outfit: 100% Polyester Muumuu

Time: 30 seconds Burn I.D. No.: 2-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms

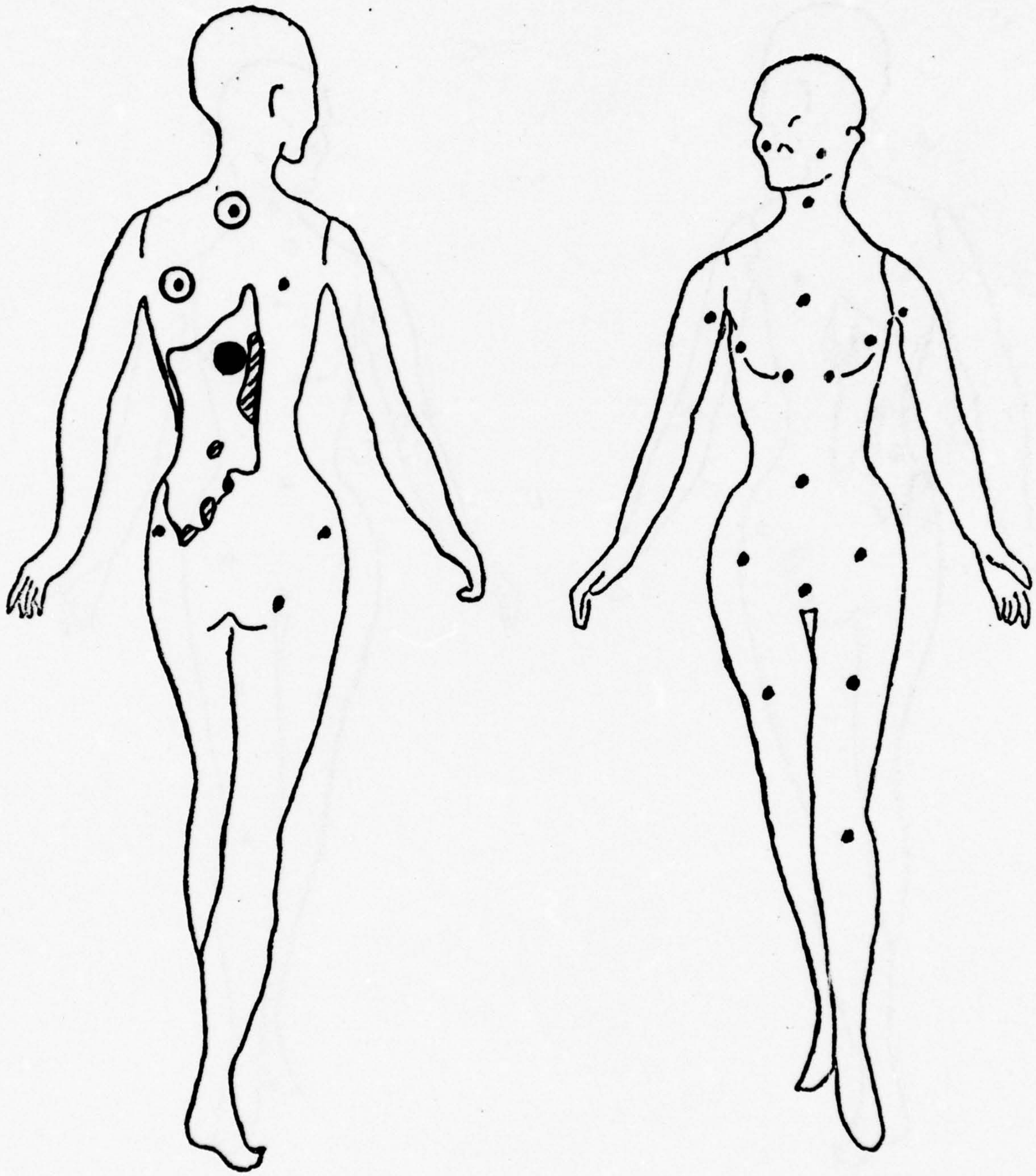


Airline No.: 3 Ignition: Left Back

Outfit: 100% Polyester Muumuu

Time: 45 seconds Burn I.D. No.: 2-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 3 Ignition: Left Back

Outfit: 100% Polyester Muumuu

Time: 60 seconds Burn I.D. No.: 2-3

BURN #3 - 1, 2, 3

Underwear: Bra - 100% polyester, unlabeled foam padding

Panties - 100% nylon

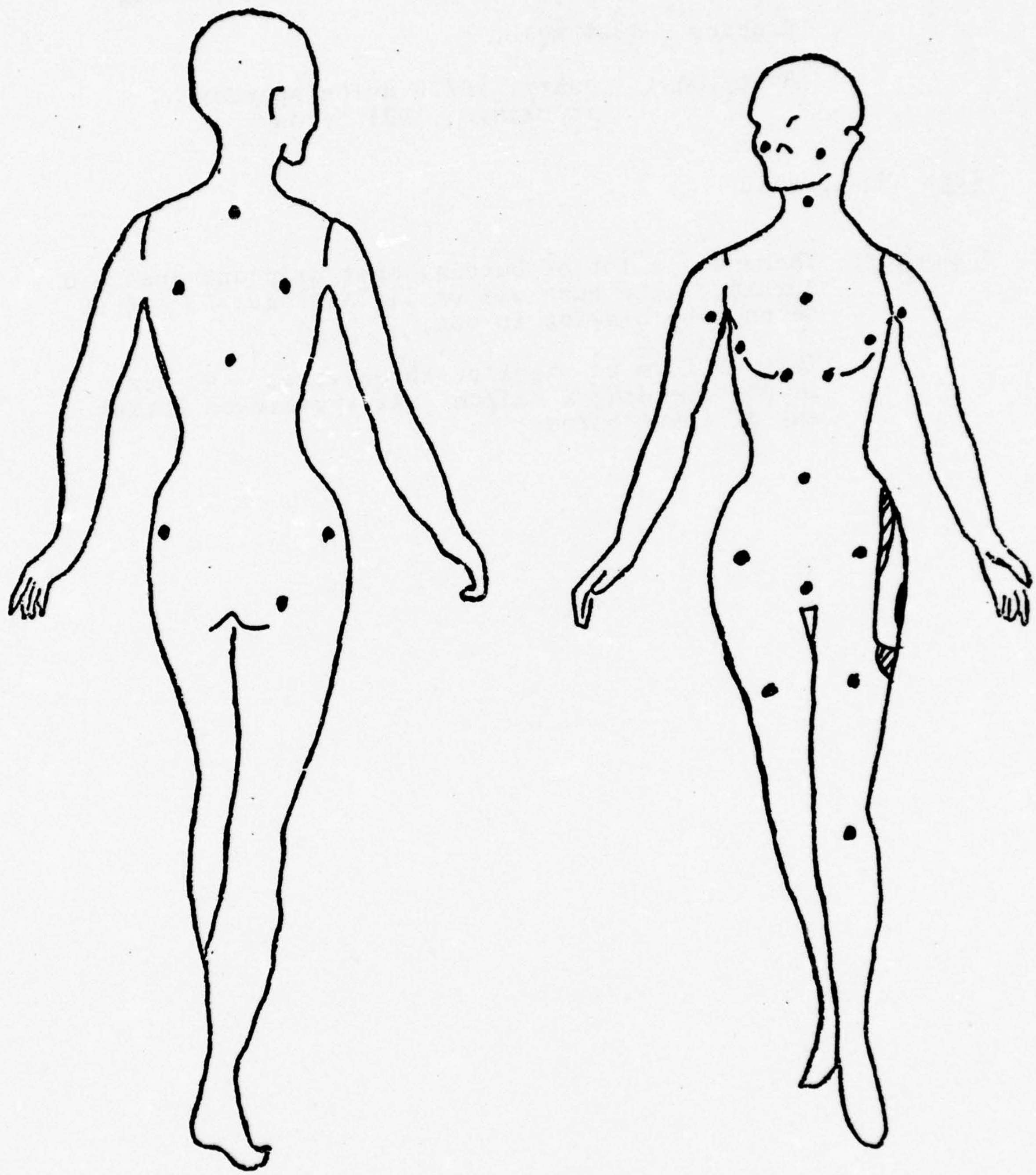
Panty Hose - panty, 80/20 nylon/spandex
stockings, 100% nylon

Wig: Modacrylic

Comments: There was a lot of burning melt drip and downward burning. The burn was easily extinguished at 90 seconds by blowing it out.

This uniform was ignited three times. No heat input exceeding 2 cal/cm^2 was registered during any of these burns.

Heat Input to Mannequin From Burning Flight Attendant Uniforms

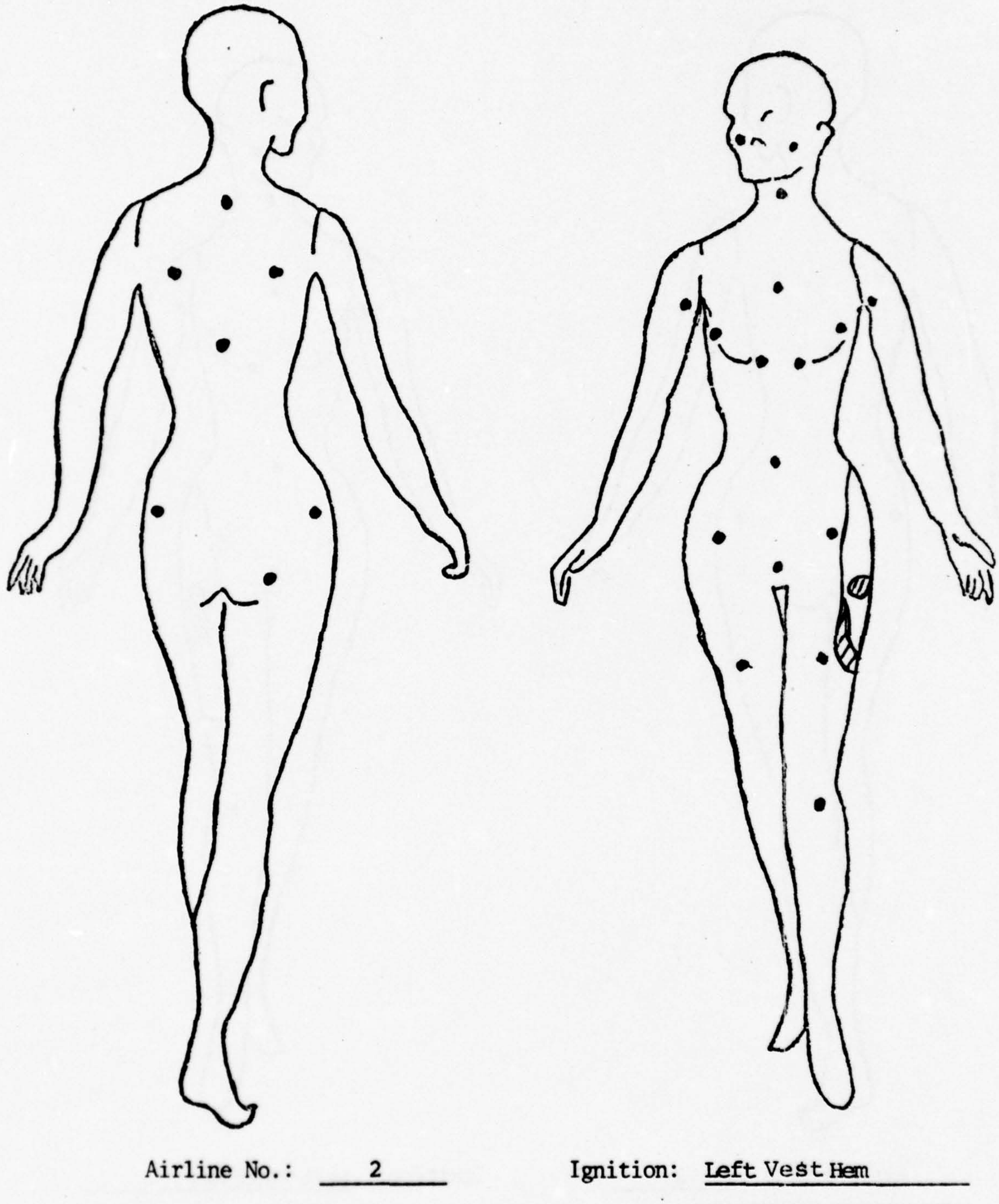


Airline No.: 2   Ignition: Left Vest Hem

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 15 seconds   Burn I.D. No.: 3-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

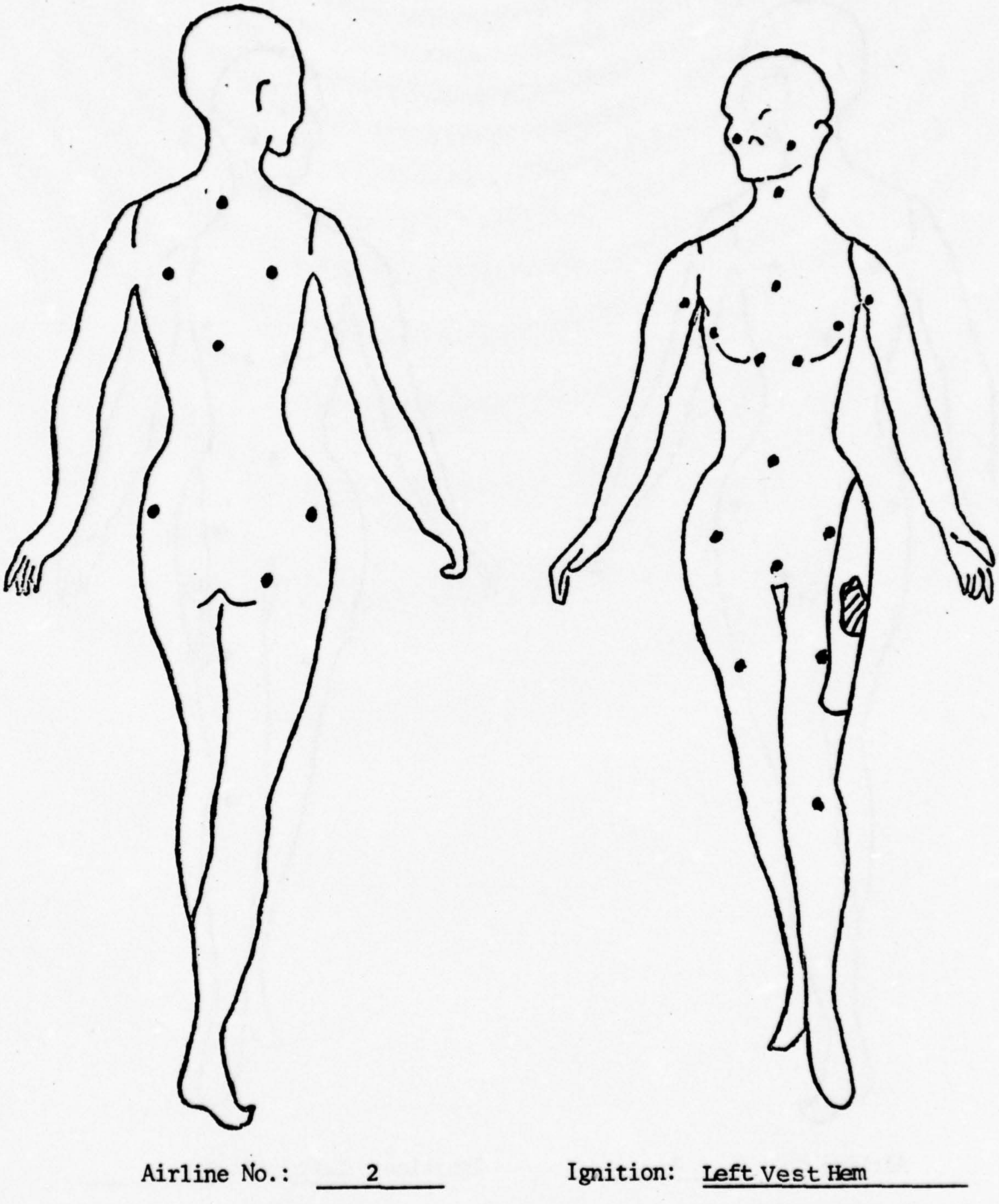


Airline No.: 2 Ignition: Left Vest Hem

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 30 seconds Burn I.D. No.: 3-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 2

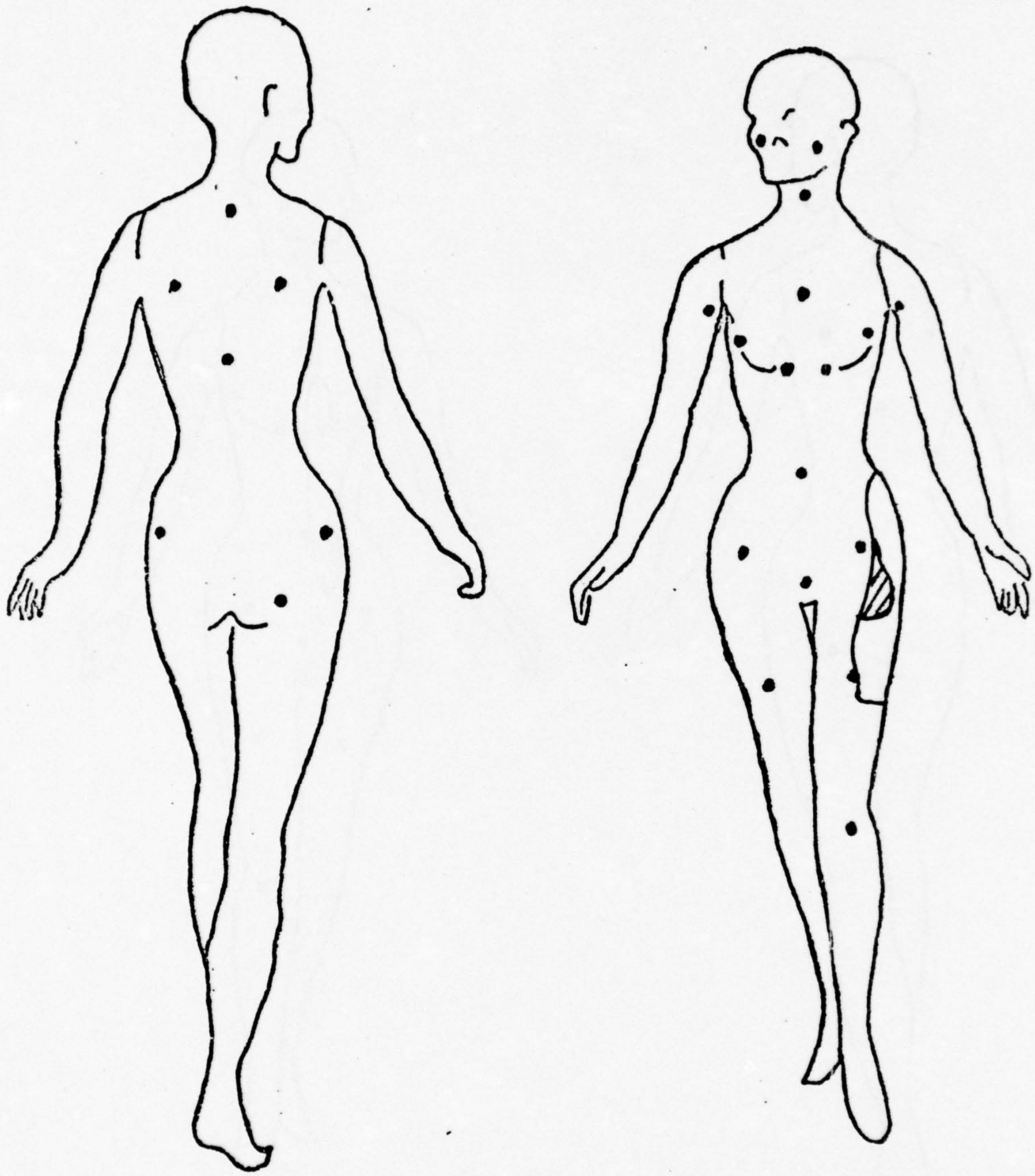
Ignition: Left Vest Hem

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 45 seconds

Burn I.D. No.: 3-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 2

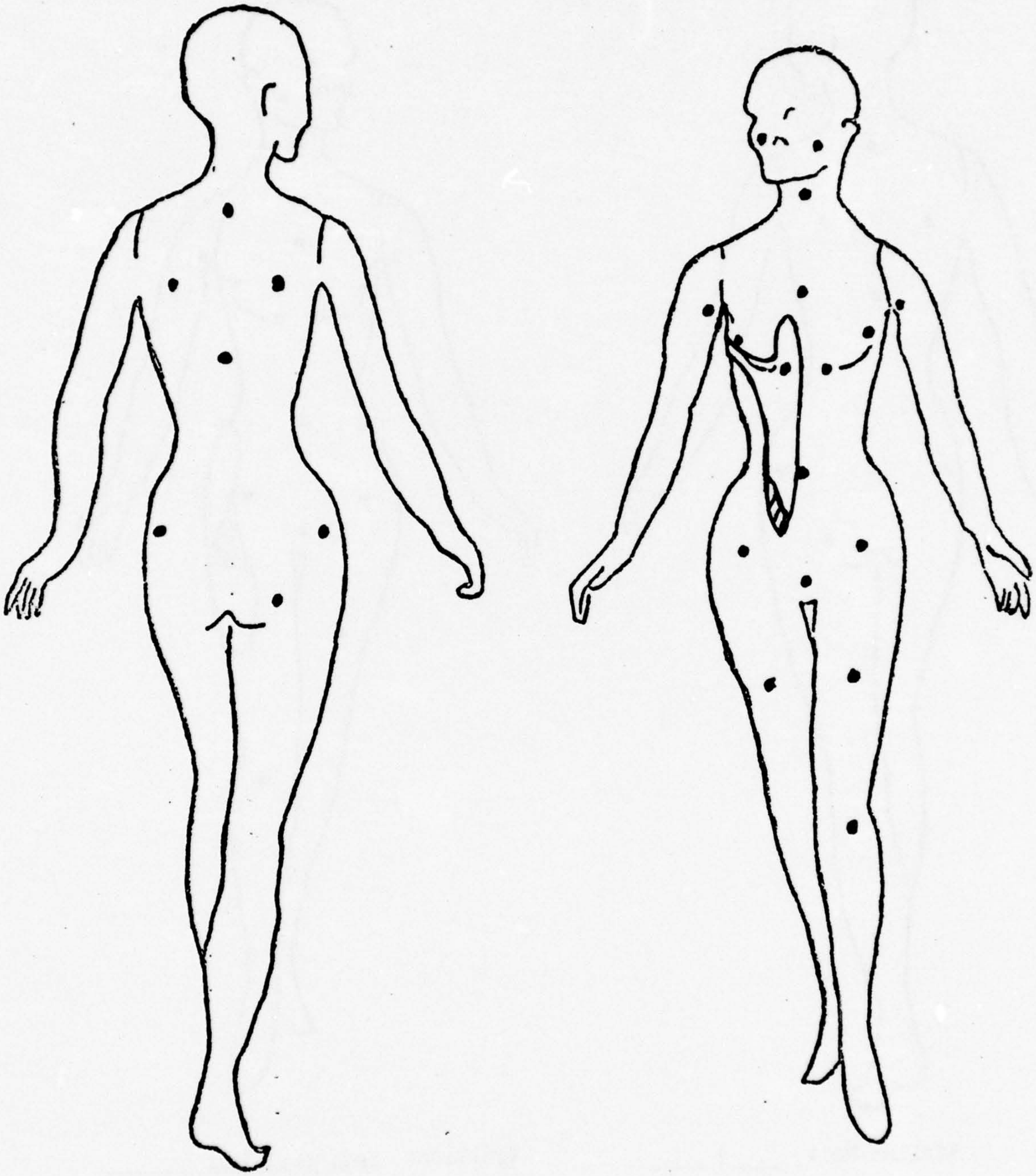
Ignition: Left Vest Hem

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 60 seconds

Burn I.D. No.: 3-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

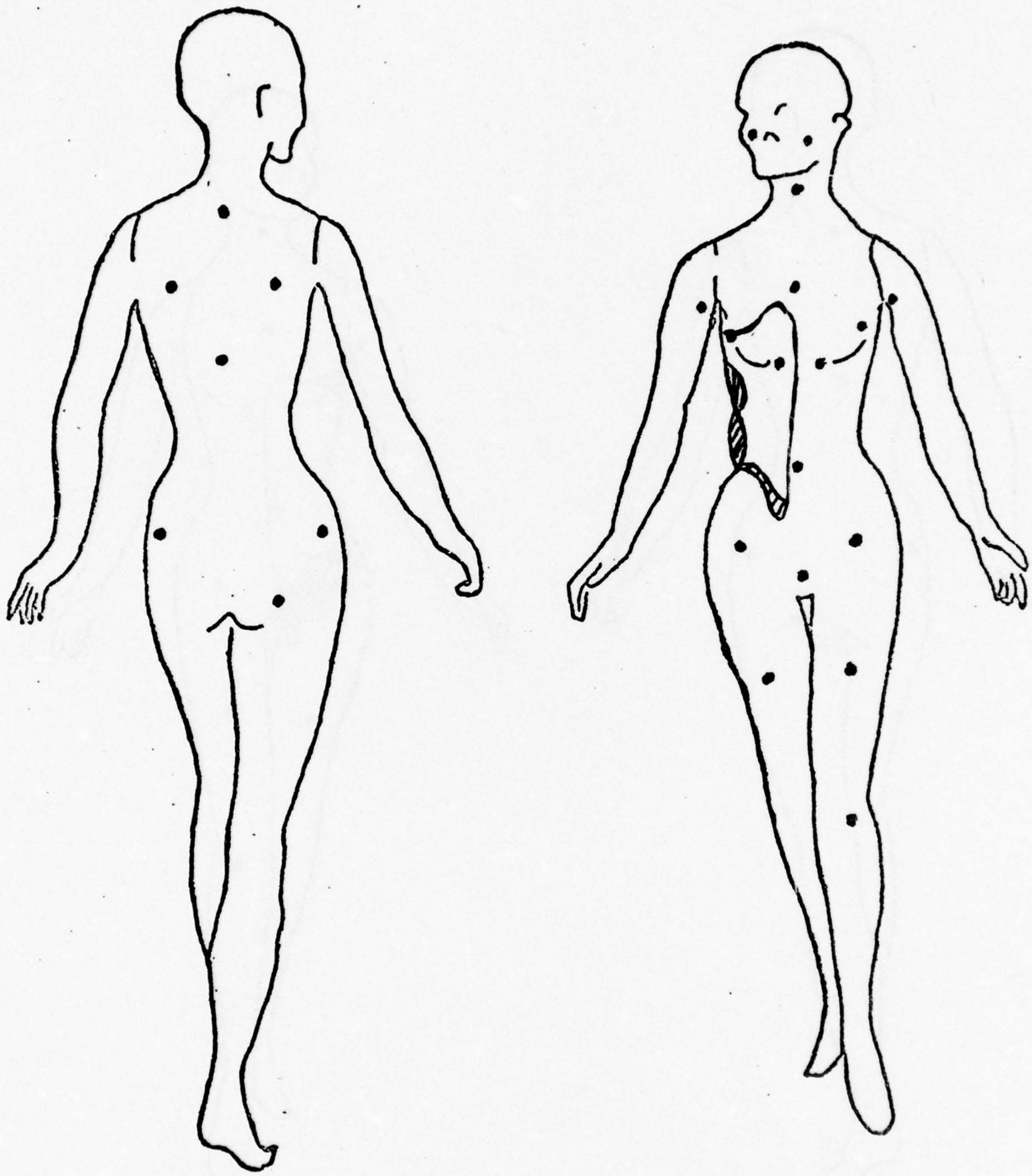


Airline No.: 2 Ignition: Right Chest

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 15 seconds Burn I.D. No.: 3-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

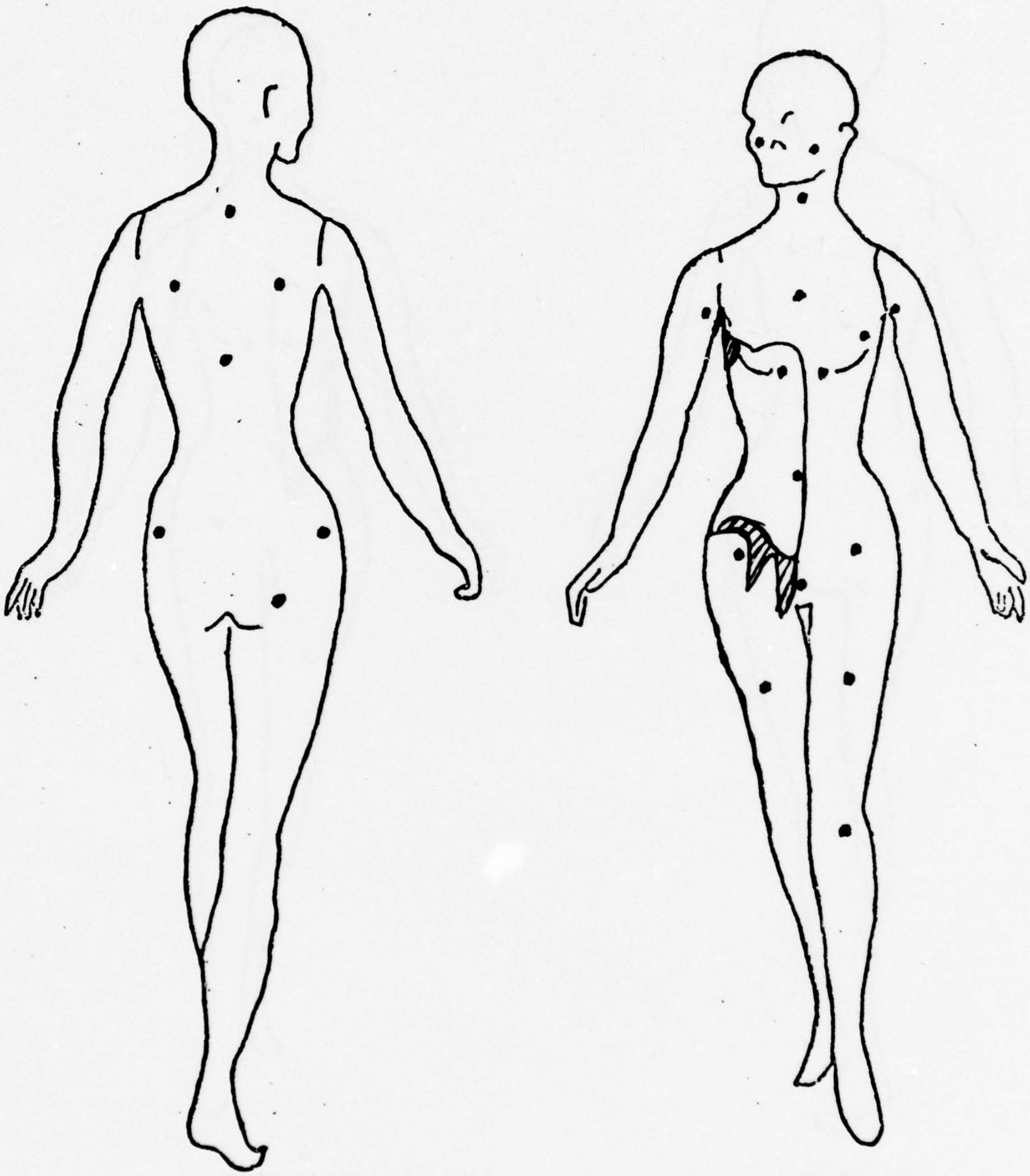


Airline No.: 2 Ignition: Right Chest

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 30 seconds Burn I.D. No.: 3-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 2

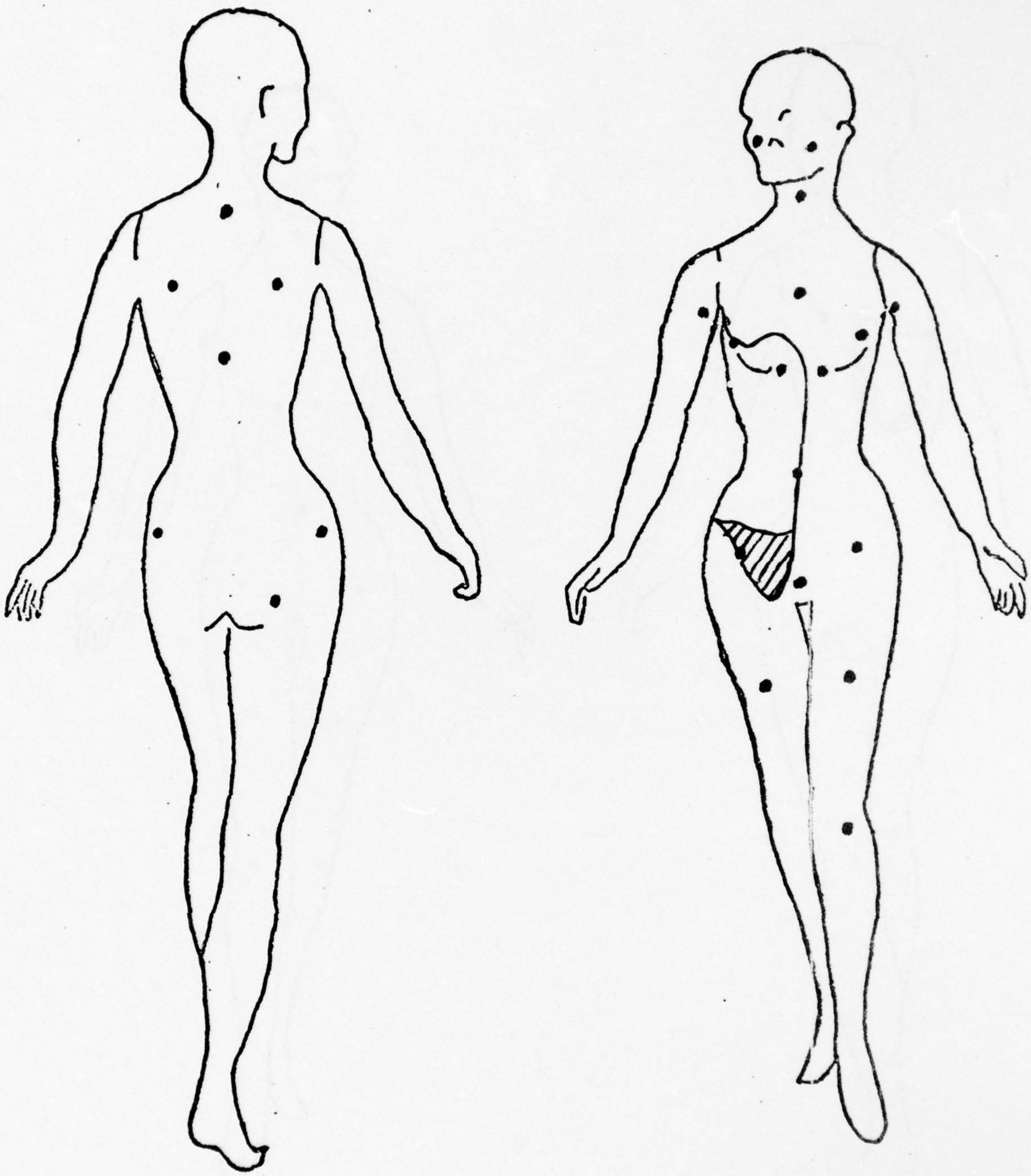
Ignition: Right Chest

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 45 seconds

Burn I.D. No.: 3-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

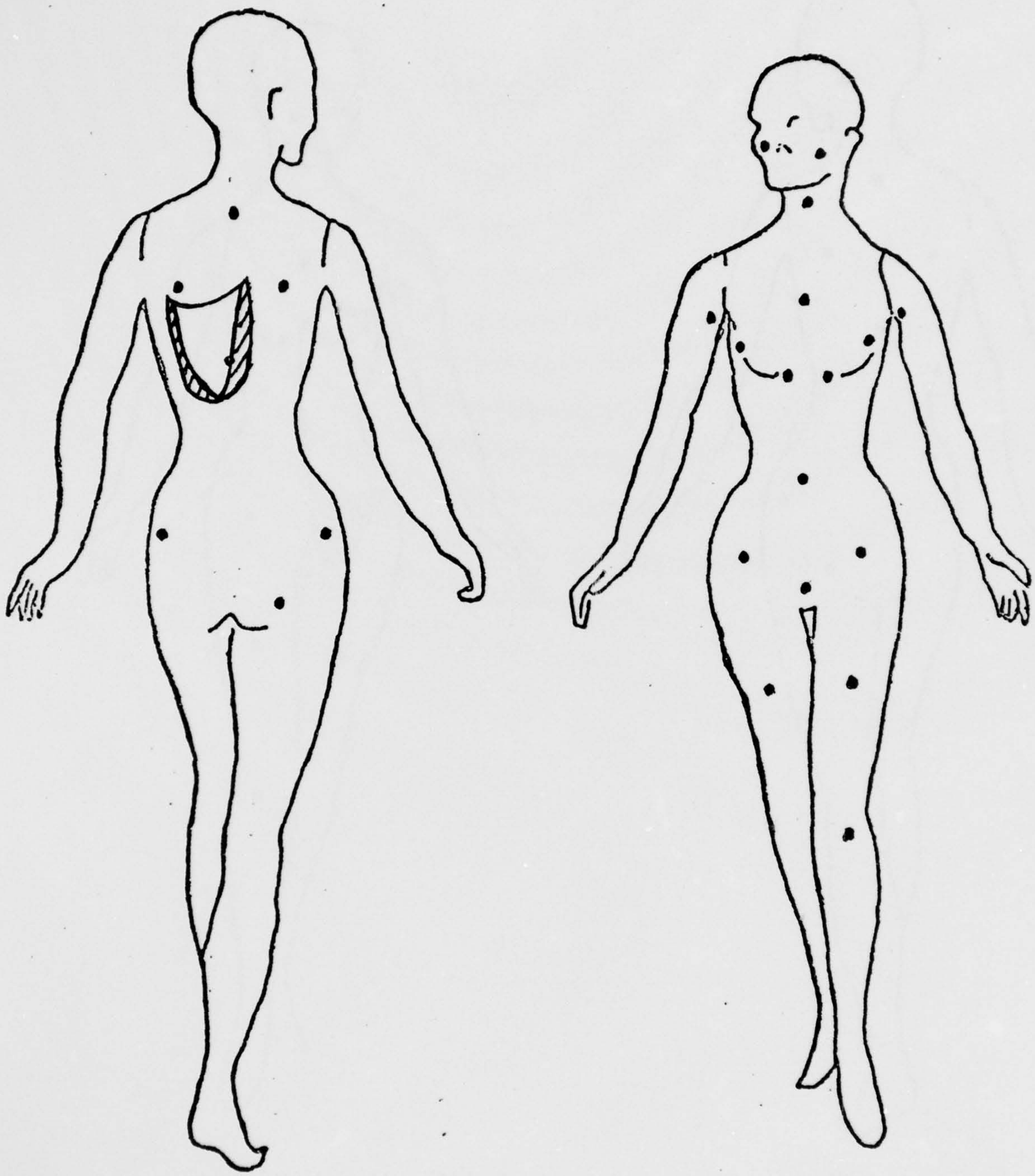


Airline No.: 2 Ignition: Right Chest

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 60 seconds Burn I.D. No.: 3-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

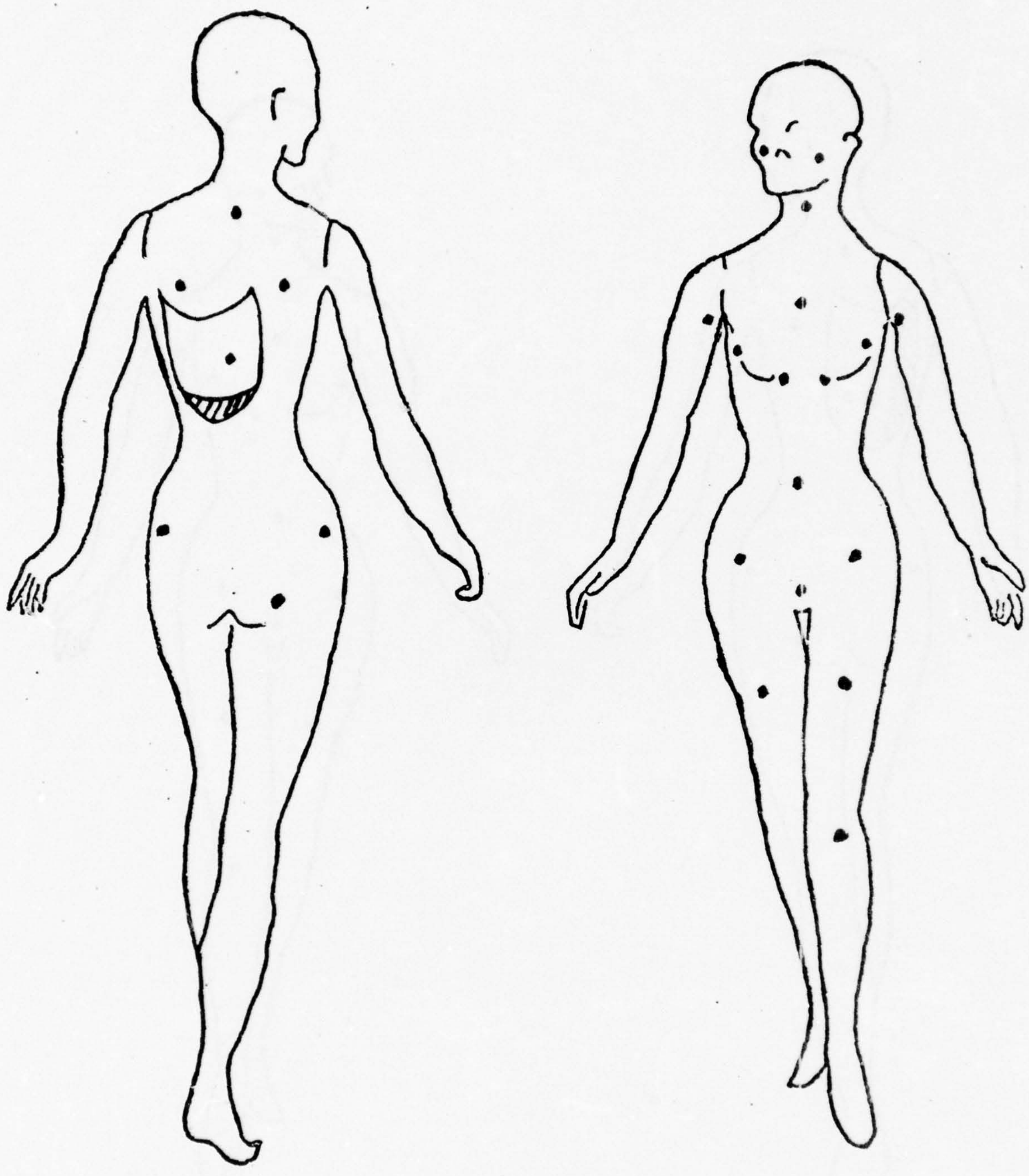


Airline No.: 2 Ignition: Left Back

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 15 seconds Burn I.D. No.: 3-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms

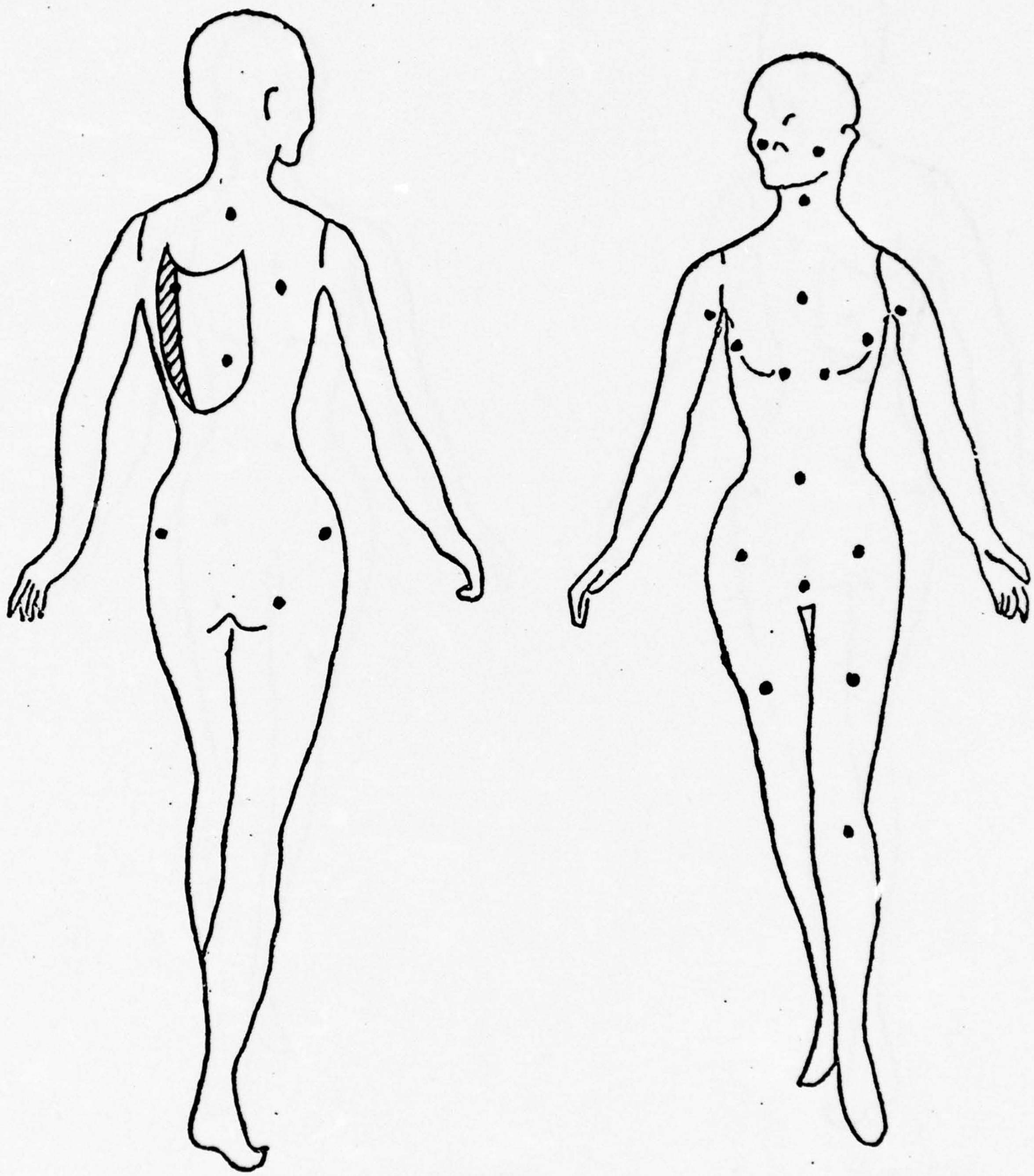


Airline No.: 2 Ignition: Left Back

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 30 seconds Burn I.D. No.: 3-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms

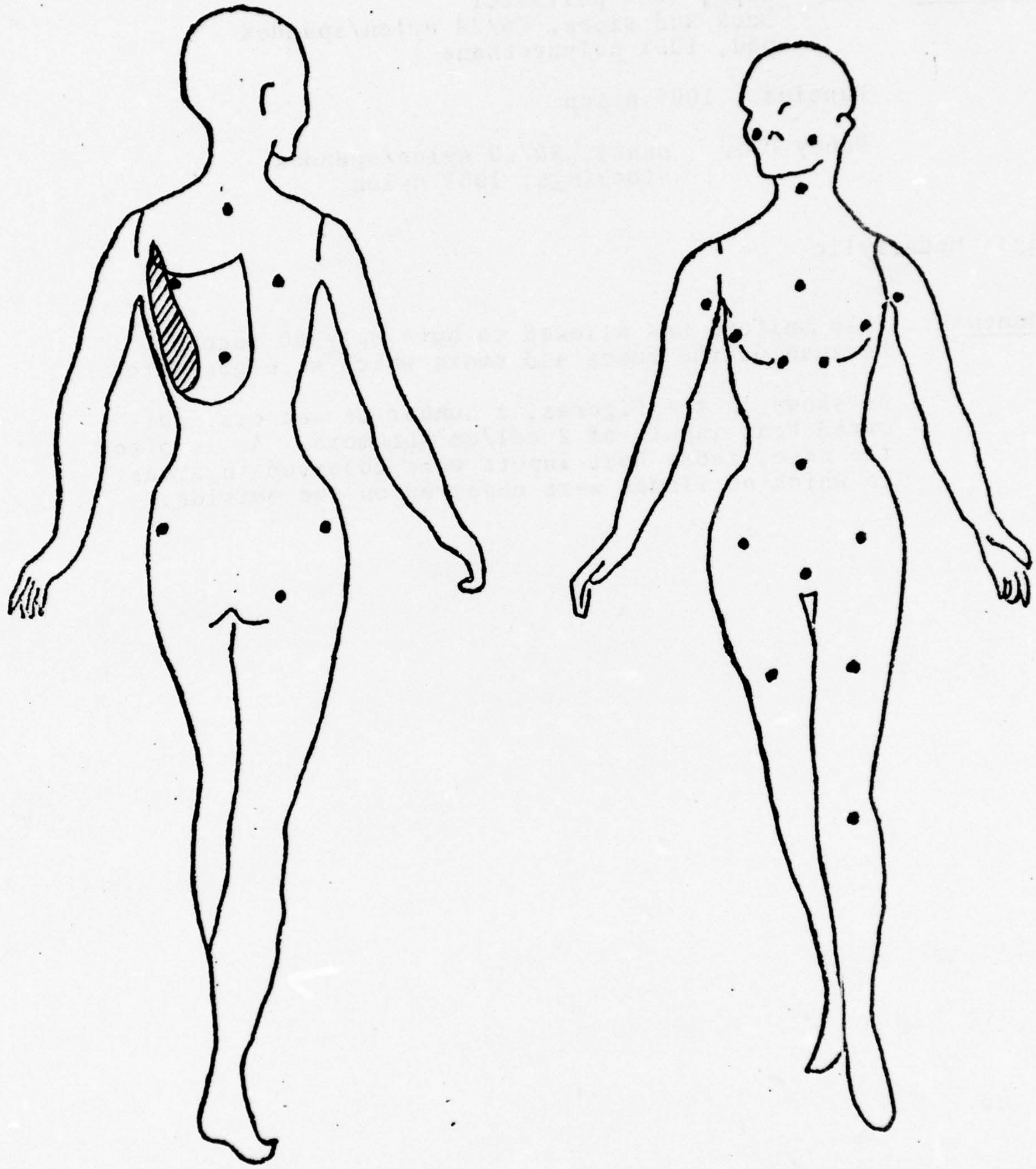


Airline No.: 2 Ignition: Left Back

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 45 seconds Burn I.D. No.: 3-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 2 Ignition: Left Back

Outfit: 100% Polyester Pants, Vest, and Scarf
100% Nylon Blouse

Time: 60 seconds Burn I.D. No.: 3-3

BURN #4 - 1

Underwear: Bra - cups, 100% polyester
back and sides, 76/24 nylon/spandex
pad, 100% polyurethane

Panties: 100% nylon

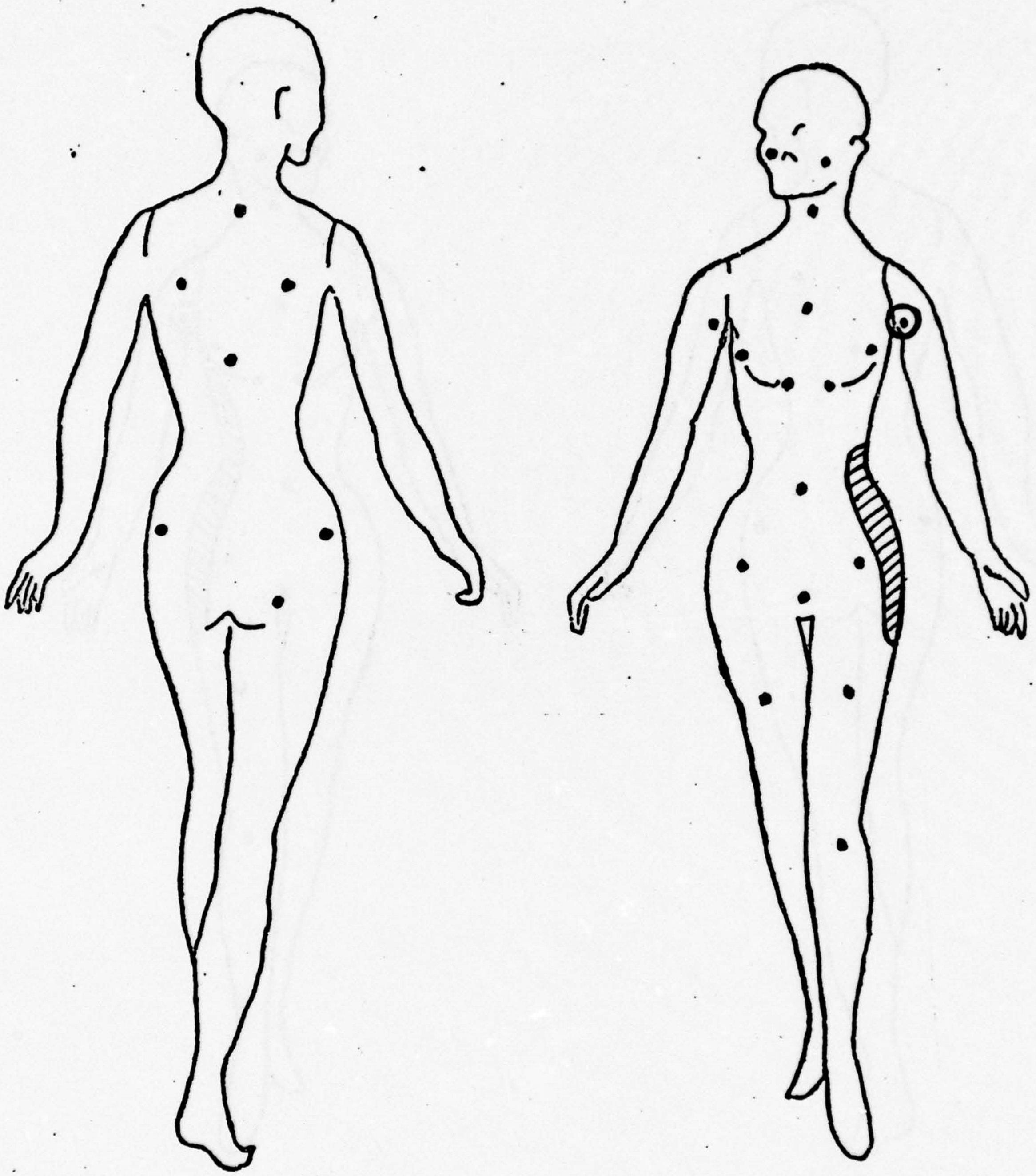
Panty Hose - panty, 80/20 nylon/spandex
stockings, 100% nylon

Wig: Modacrylic

Comments: This uniform was allowed to burn only 60 seconds because of the fumes and smoke which were generated.

As shown in the Figures, a number of sensors indicated heat inputs of 2 cal/cm^2 or more. As is often the case, these heat inputs were observed in areas in which no flames were observed on the outside.

Heat Input to Mannequin From Burning Flight Attendant Uniforms

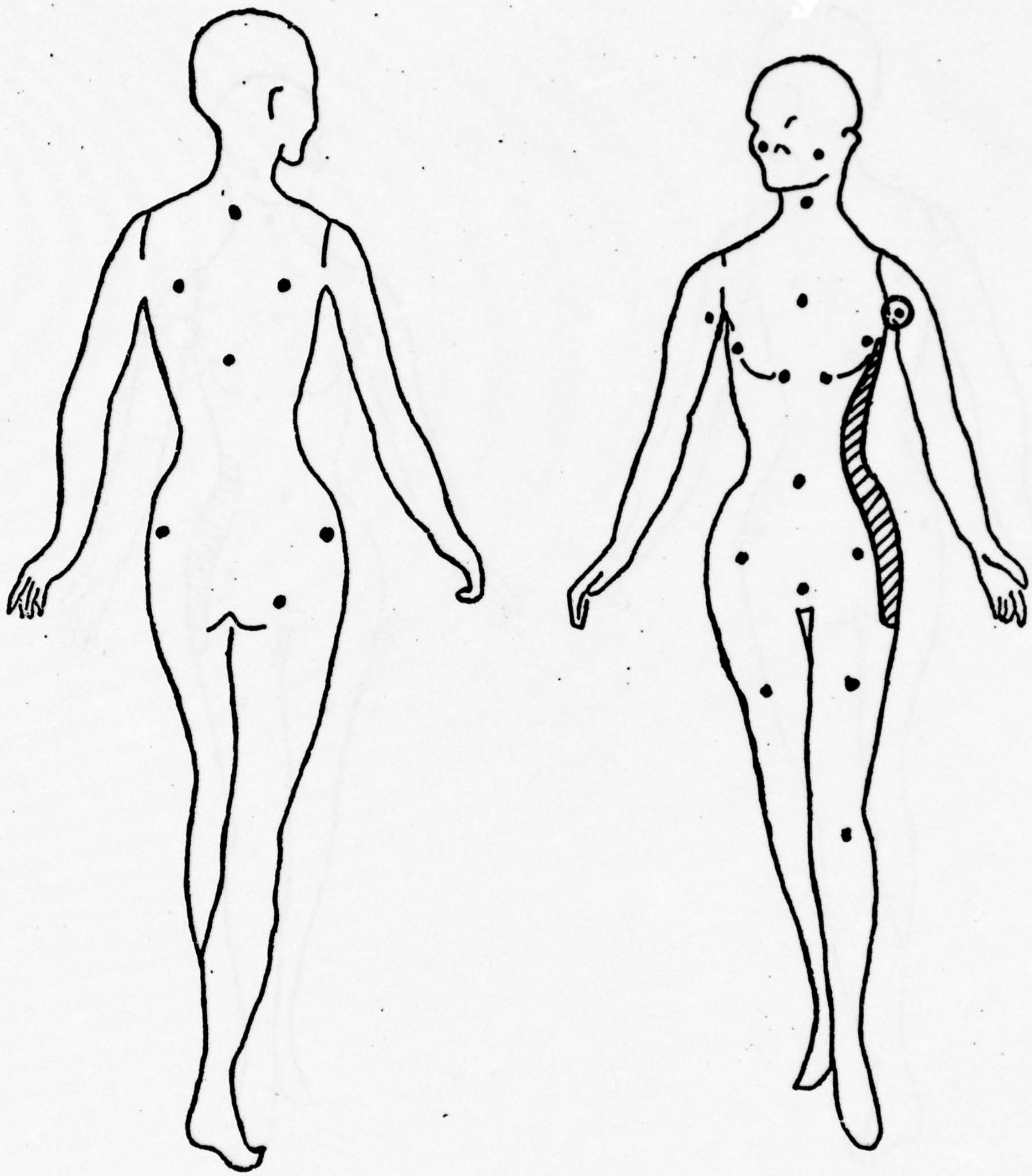


Airline No.: 4 Ignition: Left Tunic Hem

Outfit: 100% Acrylic Pants and Tunic

Time: 15 seconds Burn I.D. No.: 4-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

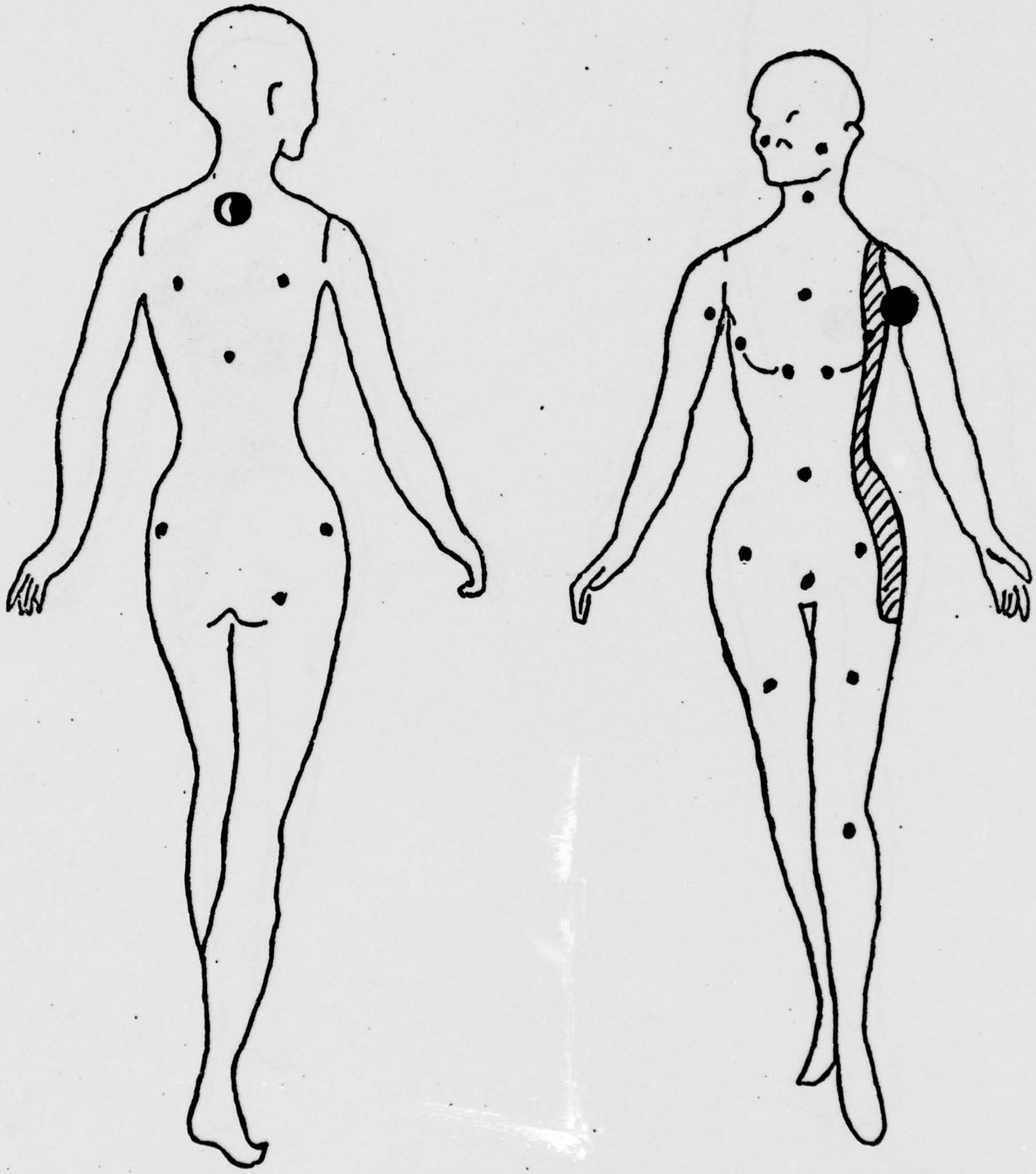


Airline No.: 4 Ignition: Left Tunic Hem

Outfit: 100% Acrylic Pants and Tunic

Time: 30 seconds Burn I.D. No.: 4-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

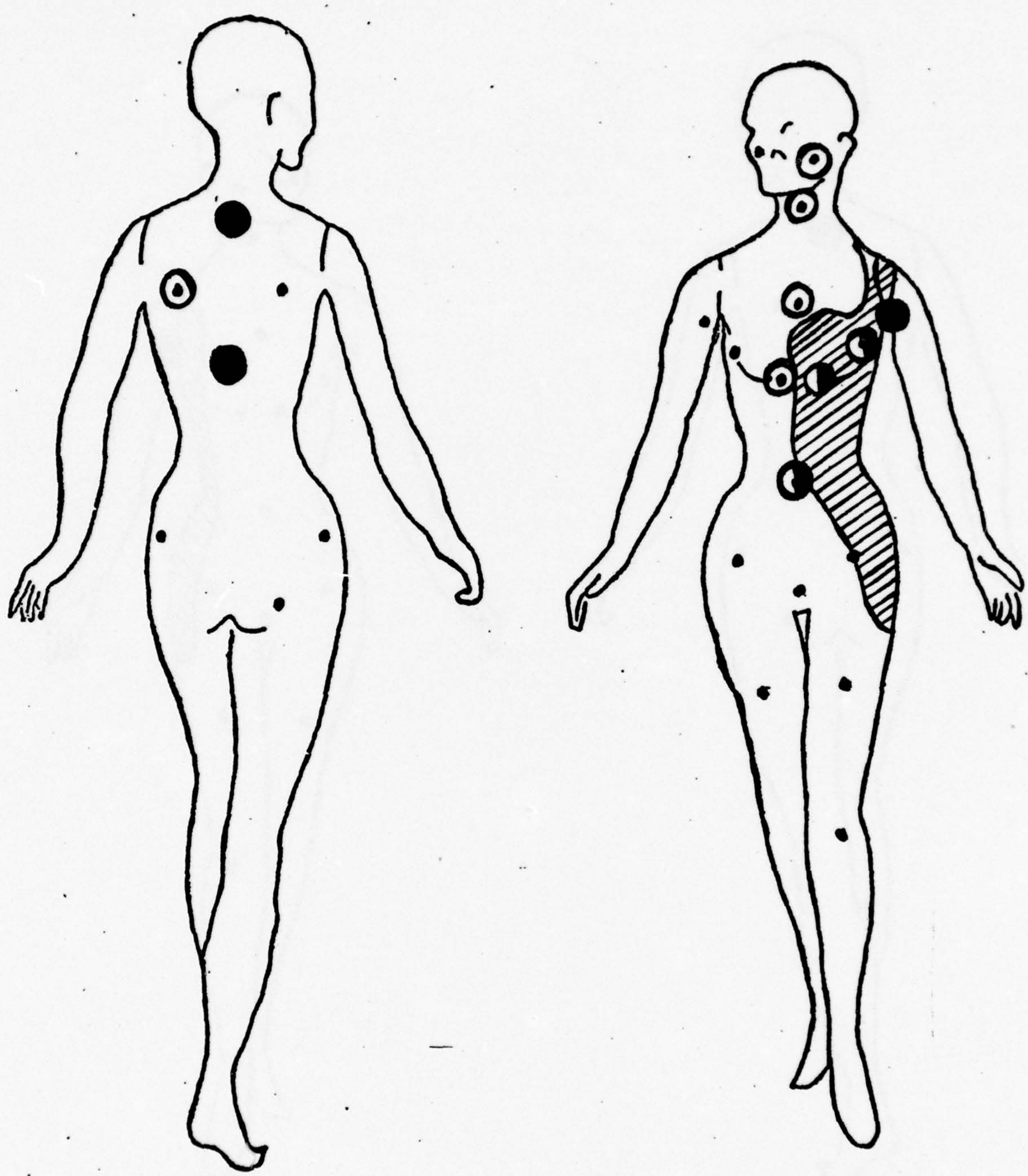


Airline No.: 4 Ignition: Left Tunic Hem

Outfit: 100% Acrylic Pants and Tunic

Time: 45 seconds Burn I.D. No.: 4-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 4 Ignition: Left Tunic Hem

Outfit: 100% Acrylic Pants and Tunic

Time: 60 seconds Burn I.D. No.: 4-1

BURN #5 - 1, 2

<u>Underwear</u>: Bra - 100% nylon with foam padding

Panties - 100% cotton

Slip - 100% nylon

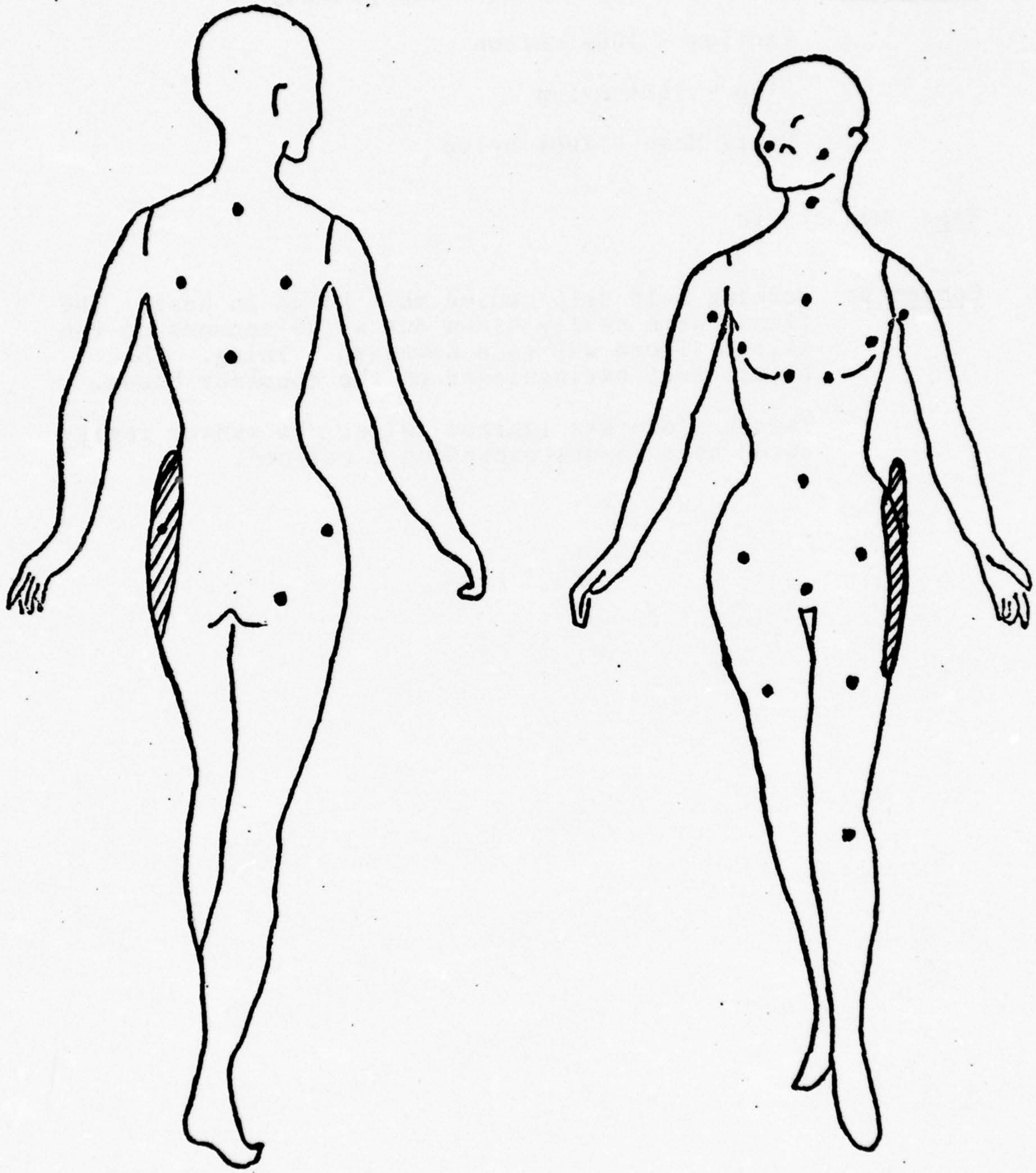
Panty Hose - 100% nylon

<u>Wig</u>: Modacrylic

<u>Comments</u>: Burning melt drip caused melt holes in hose. The flames were easily blown out at 90 seconds on the skirt. There was some downward burning. The blouse self-extinguished on the shoulder blade.

This uniform was ignited twice. No sensor registered heat inputs exceeding 2 cal/cm^2.

Heat Input to Mannequin From Burning Flight Attendant Uniforms

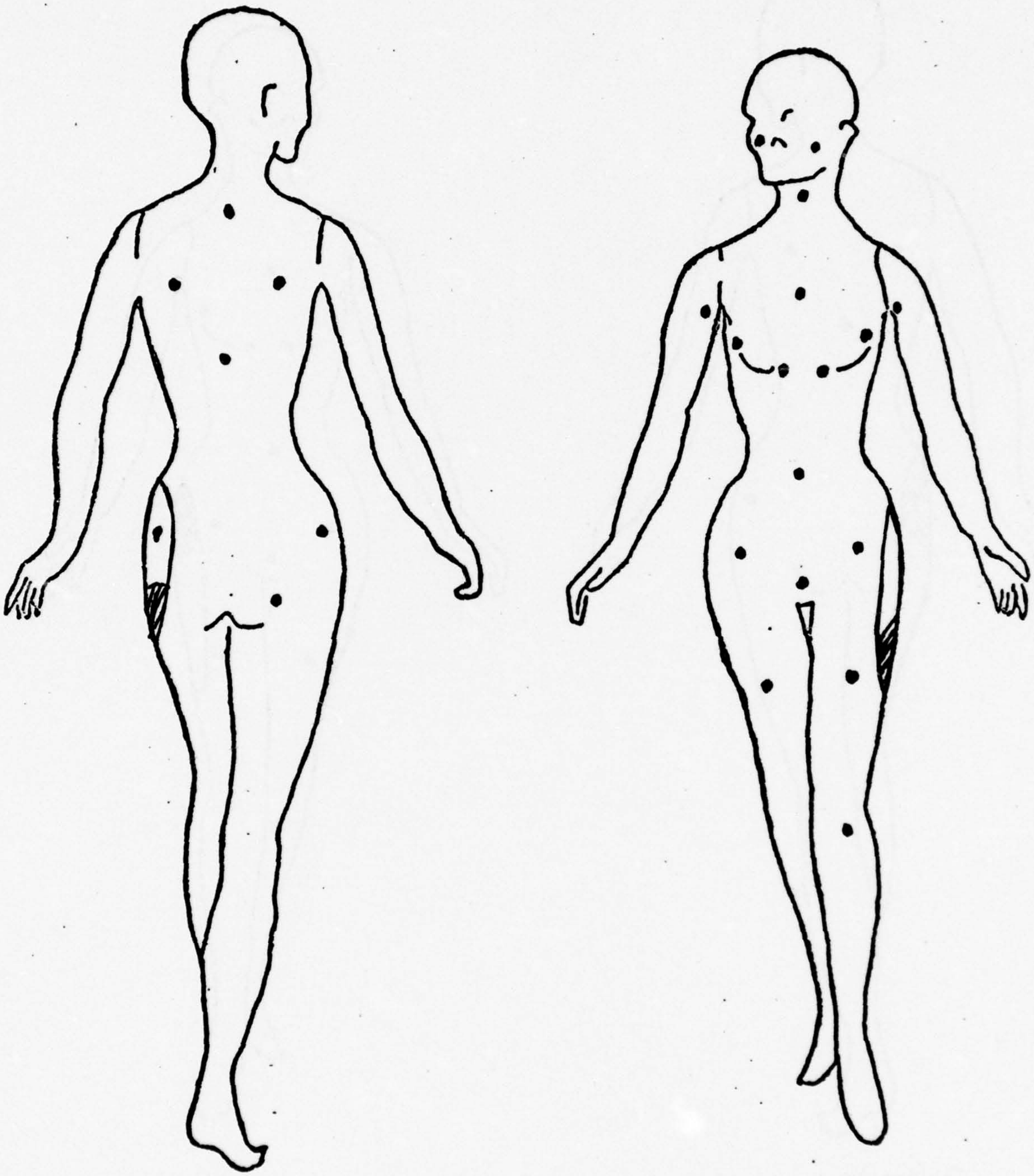


Airline No.: 5 Ignition: Left Skirt Hem

Outfit: 100% Polyester Skirt and Blouse

Time: 15 seconds Burn I.D. No.: 5-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

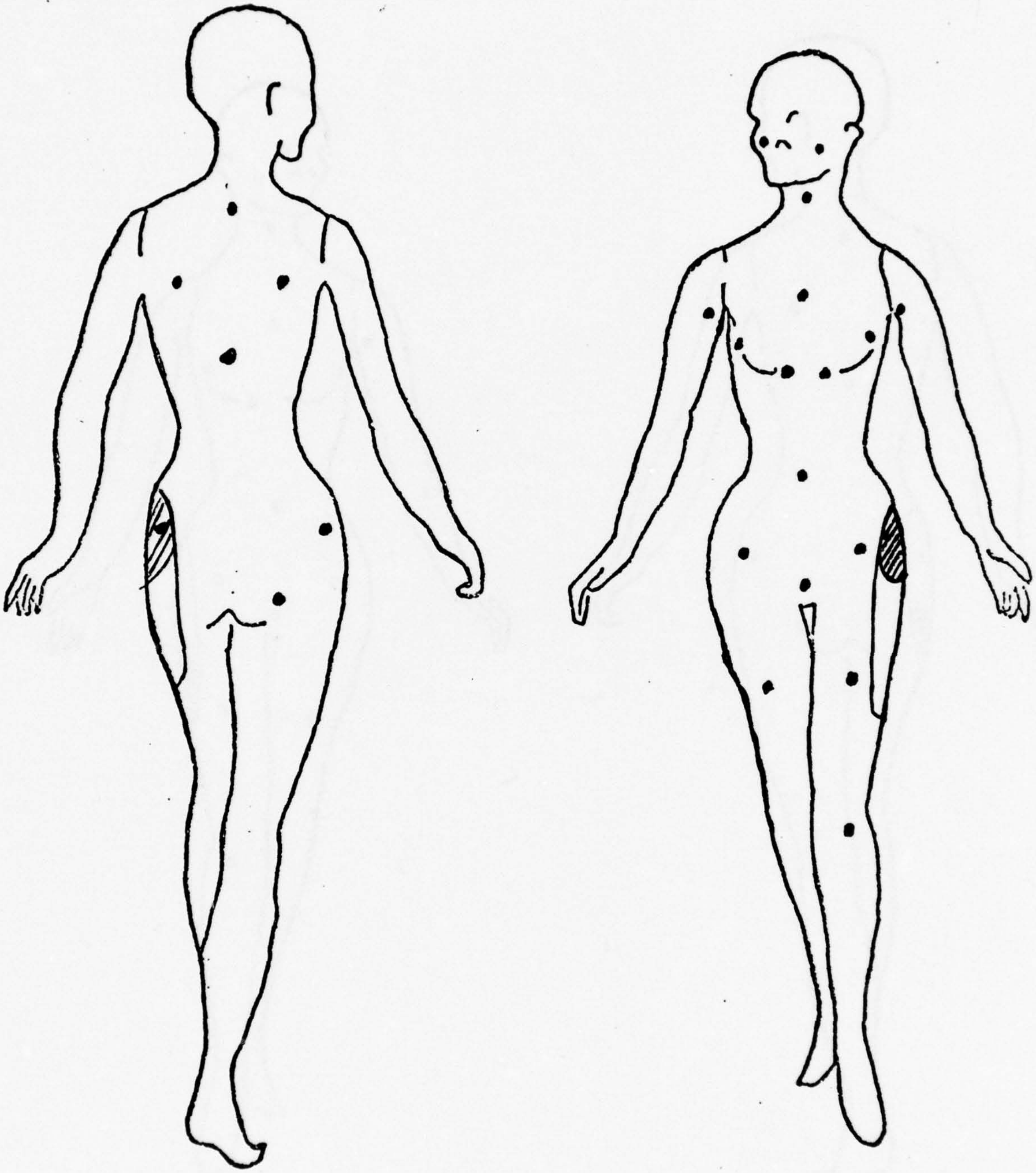


Airline No.: 5   Ignition: Left Skirt Hem

Outfit: 100% Polyester Skirt and Blouse

Time: 30 seconds   Burn I.D. No.: 5-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

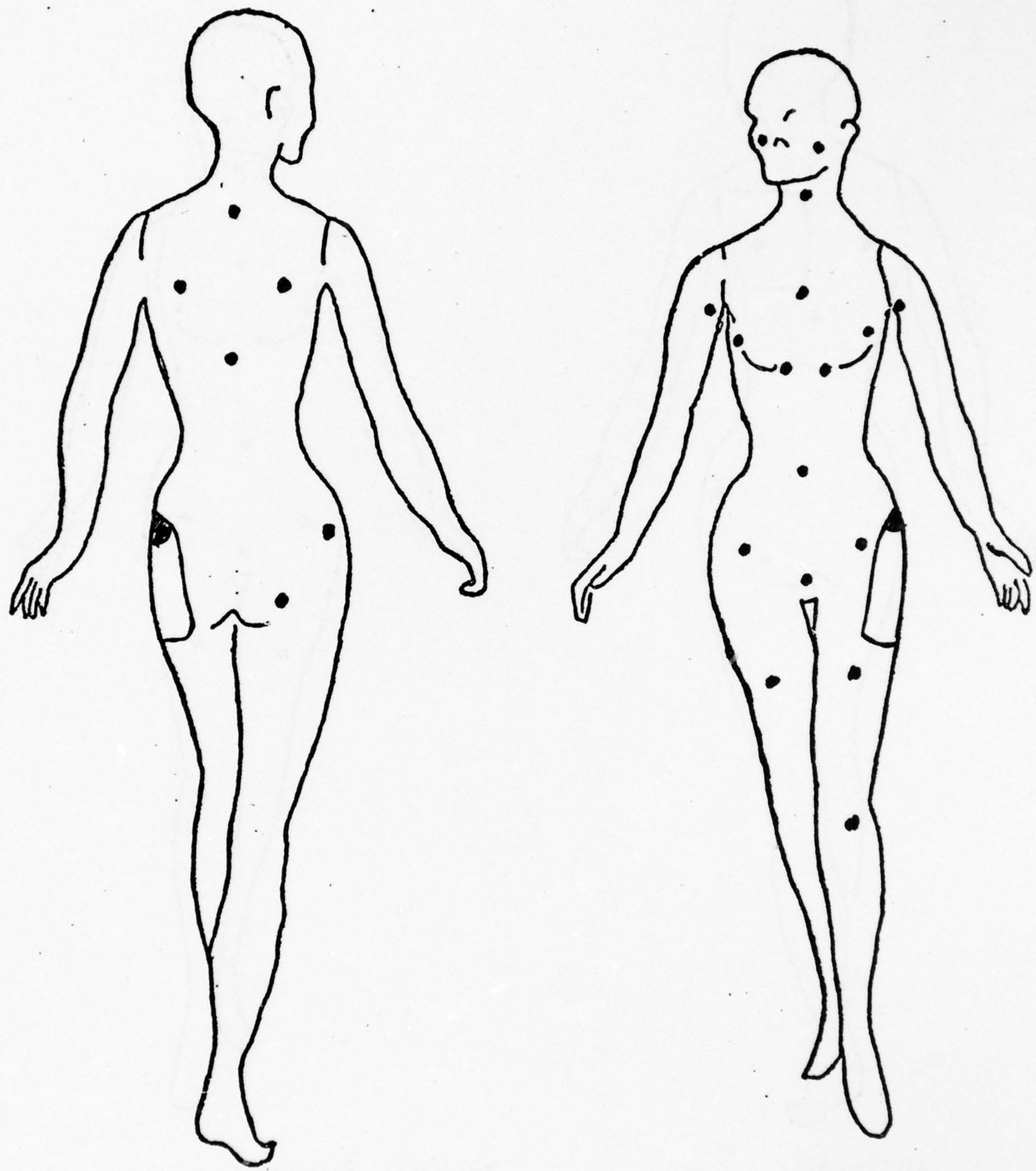


Airline No.: 5 Ignition: Left Skirt Hem

Outfit: 100% Polyester Skirt and Blouse

Time: 45 seconds Burn I.D. No.: 5-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

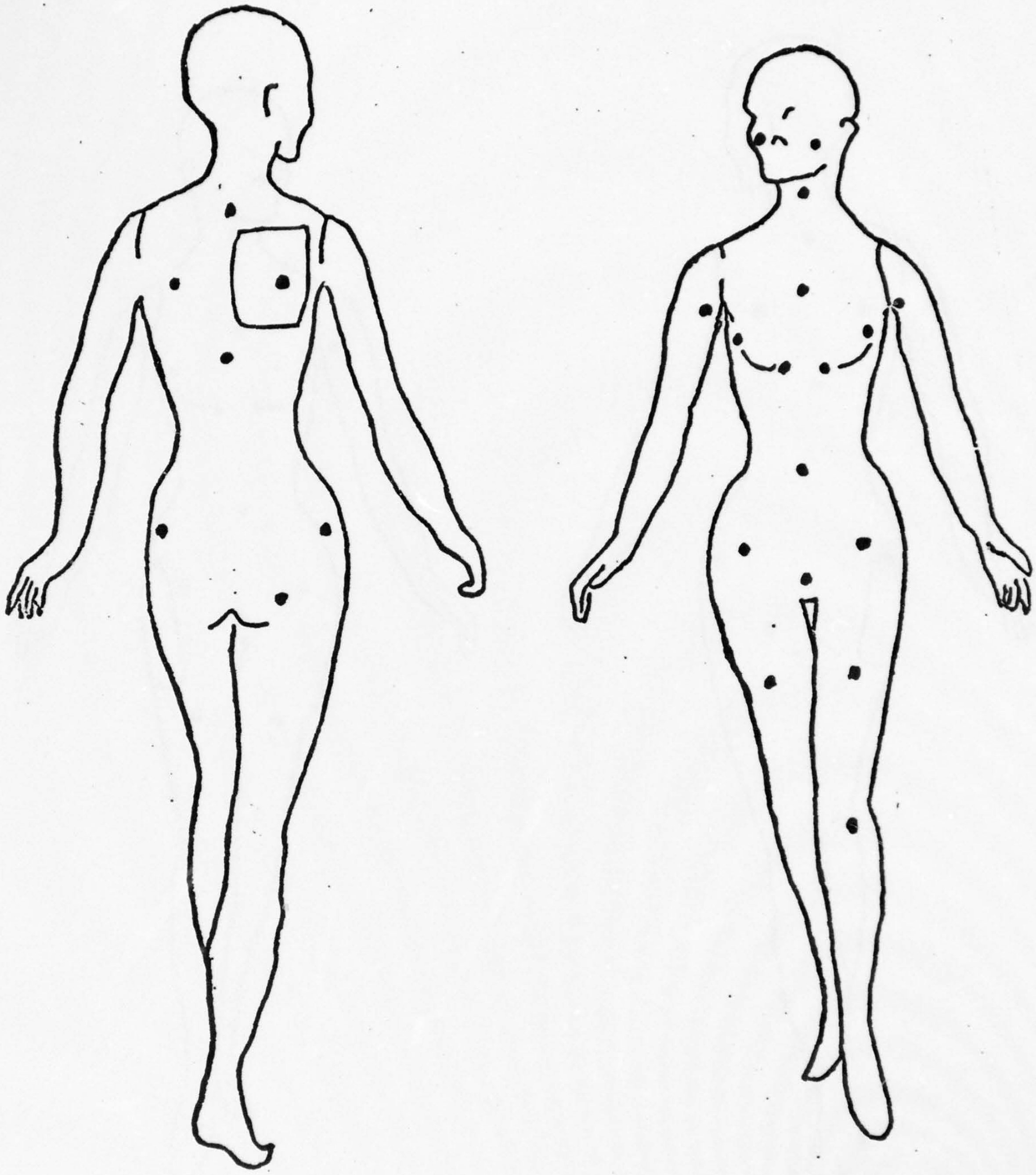


Airline No.: 5 Ignition: Left Skirt Hem

Outfit: 100% Polyester Skirt and Blouse

Time: 60 seconds Burn I.D. No.: 5-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

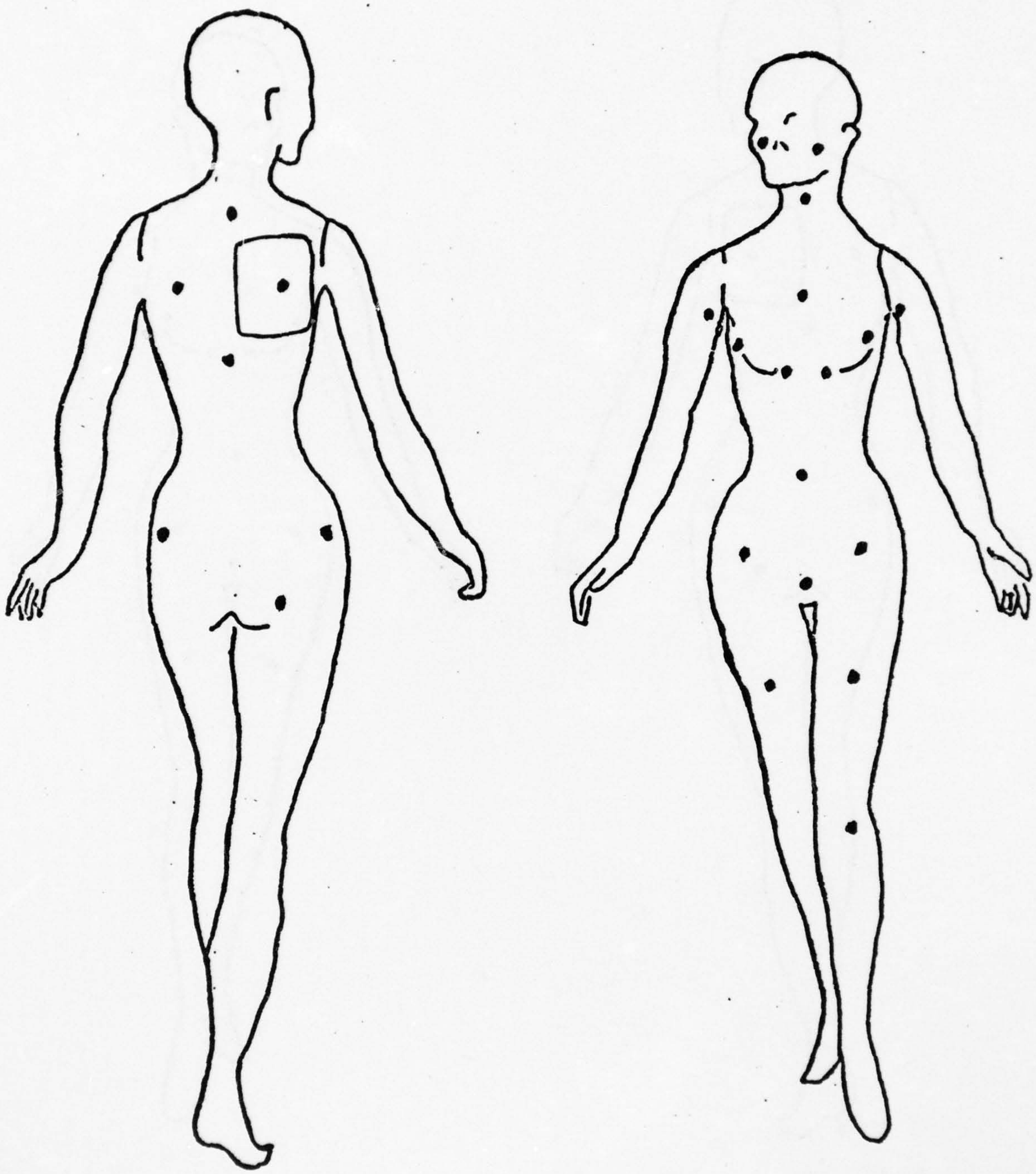


Airline No.: 5 Ignition: Right Back

Outfit: 100% Polyester Skirt and Blouse

Time: 15 seconds Burn I.D. No.: 5-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

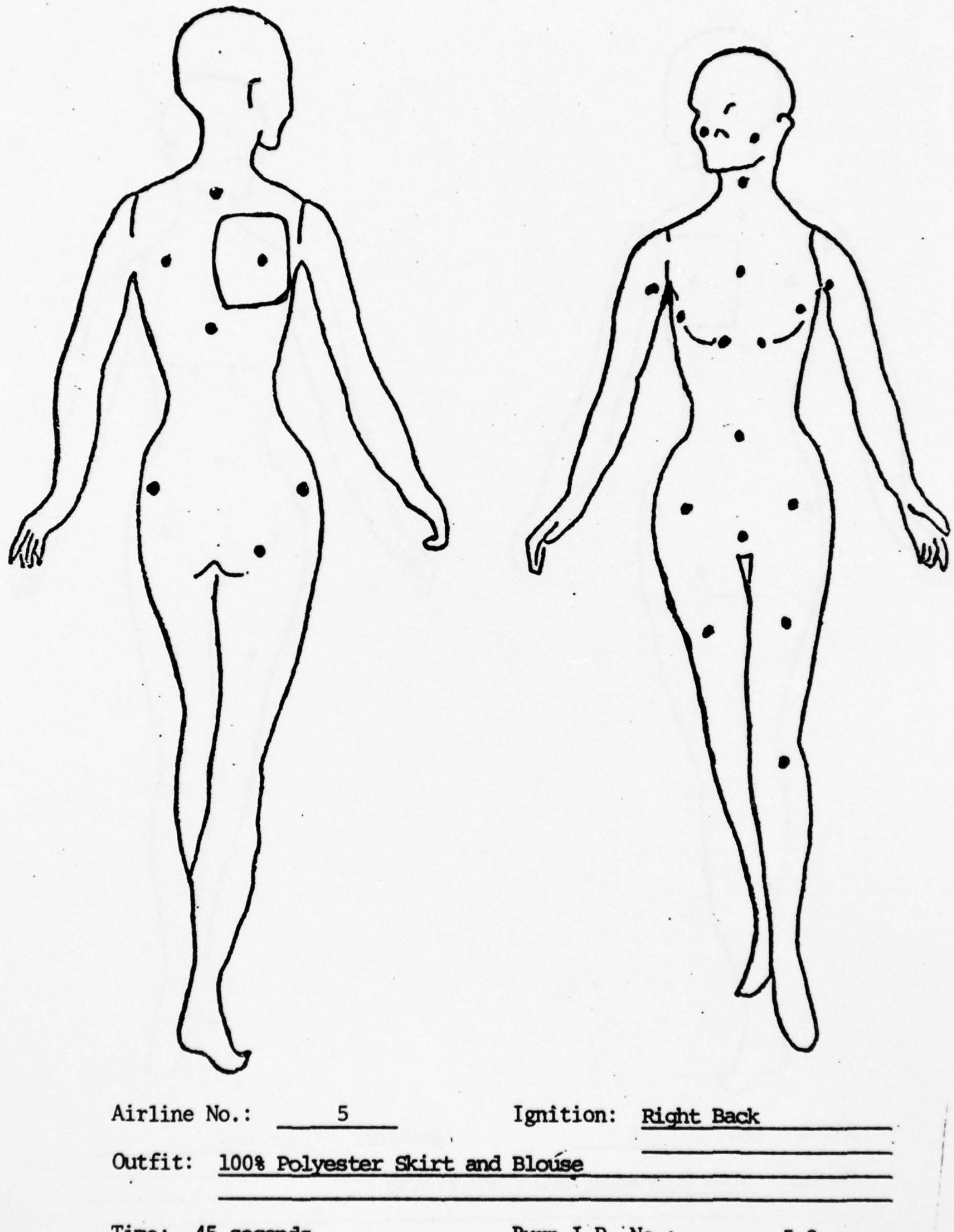


Airline No.: 5 Ignition: Right Back

Outfit: 100% Polyester Skirt and Blouse

Time: 30 seconds Burn I.D. No.: 5-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

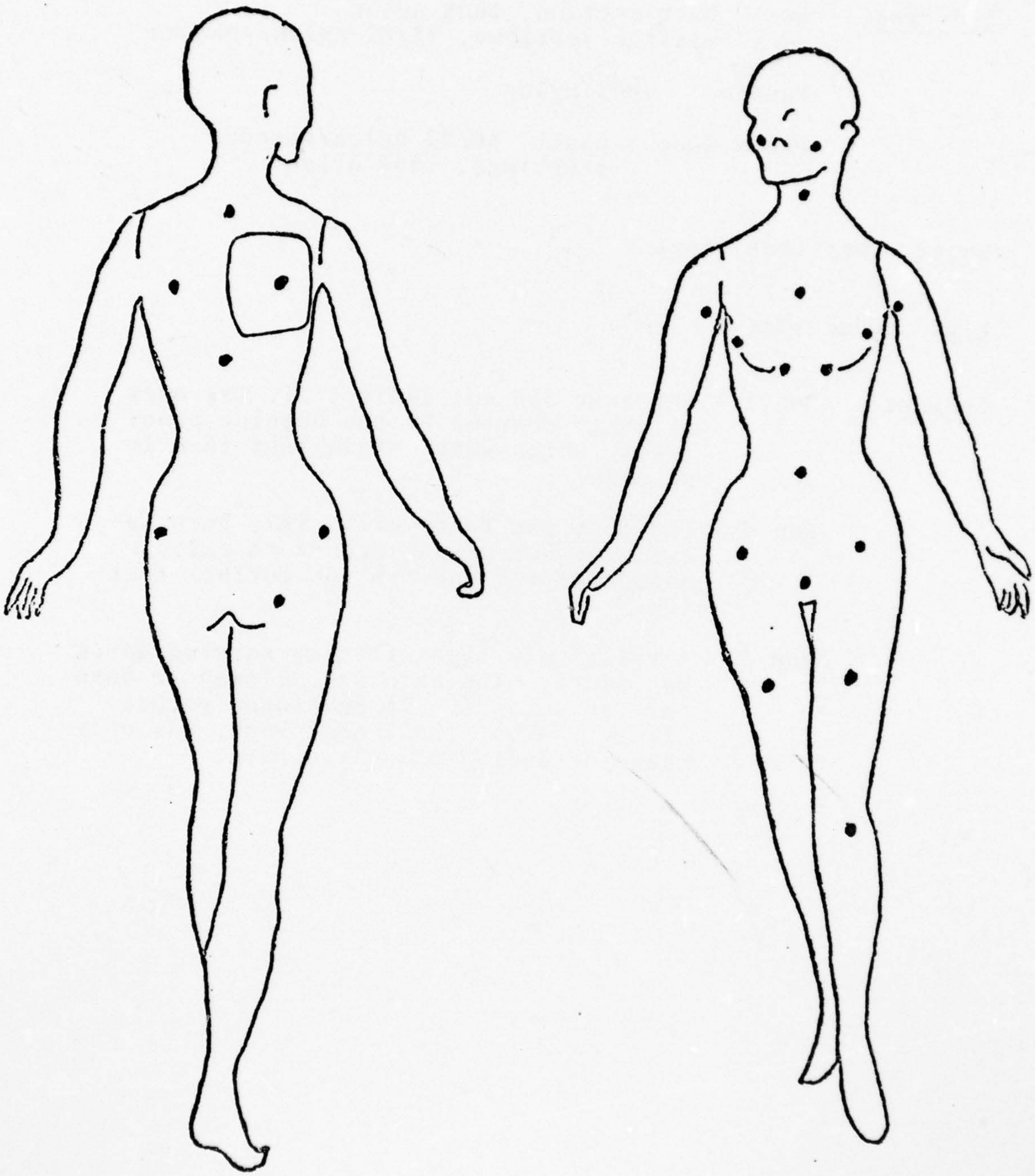


Airline No.: 5 Ignition: Right Back

Outfit: 100% Polyester Skirt and Blouse

Time: 45 seconds Burn I.D. No.: 5-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 5 Ignition: Right Back

Outfit: 100% Polyester Skirt and Blouse

Time: 60 seconds Burn I.D. No.: 5-2

BURN #6 - 1, 2, 3

Underwear: Bra - bust section, 100% nylon
elastic sections, 78/22 nylon/spandex

Panties - 100% nylon

Panty Hose - panty, 80/20 nylon/spandex
stockings, 100% nylon

Boots: Wet-Look vinyl

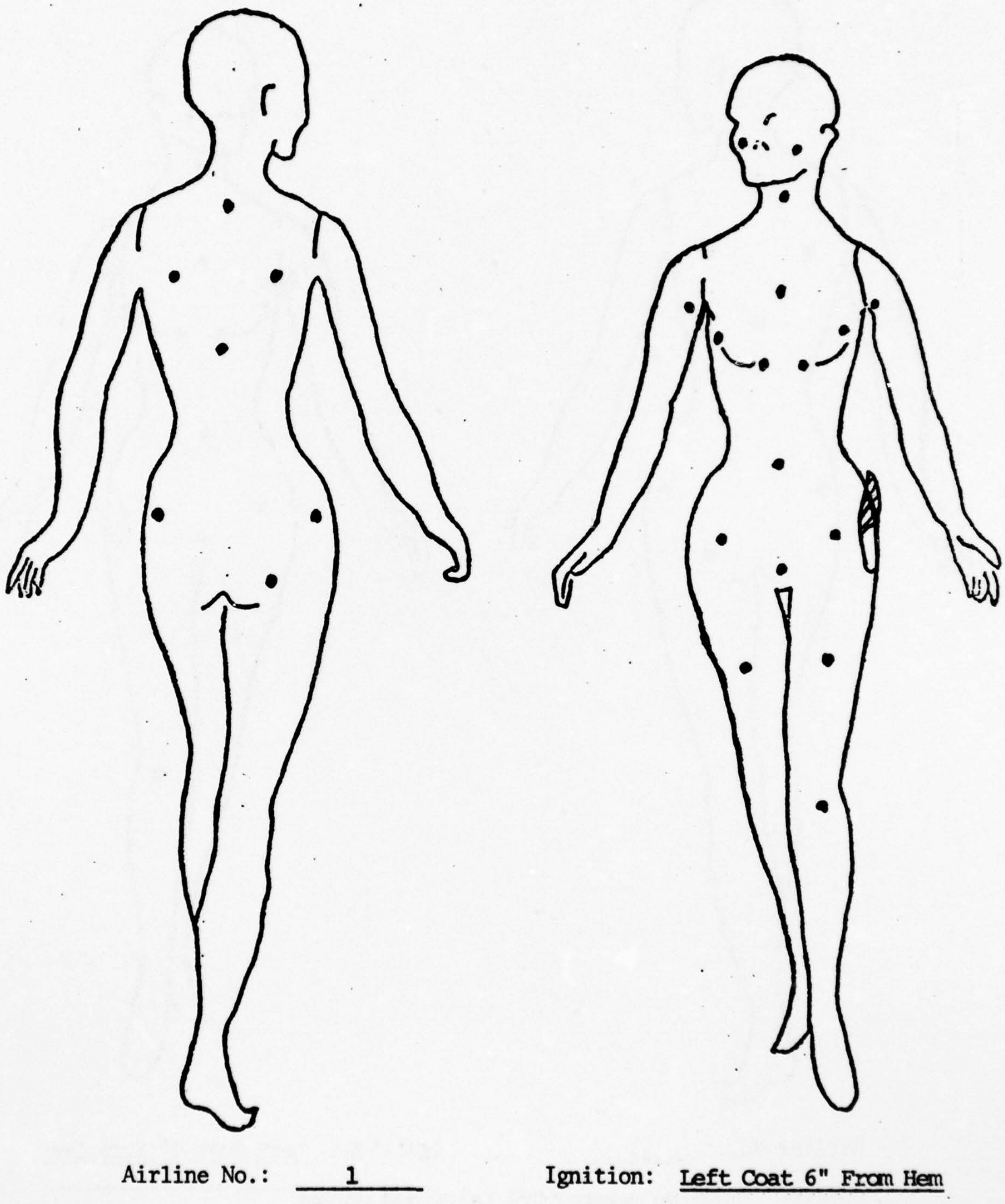
Wig: Modacrylic

Comments: Run 1 - The coat did not ignite. It was only slightly charred by the burning paper towel, which went out in less than 20 seconds.

Run 2 - The coat was taken off. This burn was extinguished at 45 seconds to salvage enough of the uniform for further testing.

Run 3 - A relatively tight-fitting serving apron was added. The burn was allowed to burn for 120 seconds. It developed rather slowly. Significant heat input was only measured during the third burn.

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

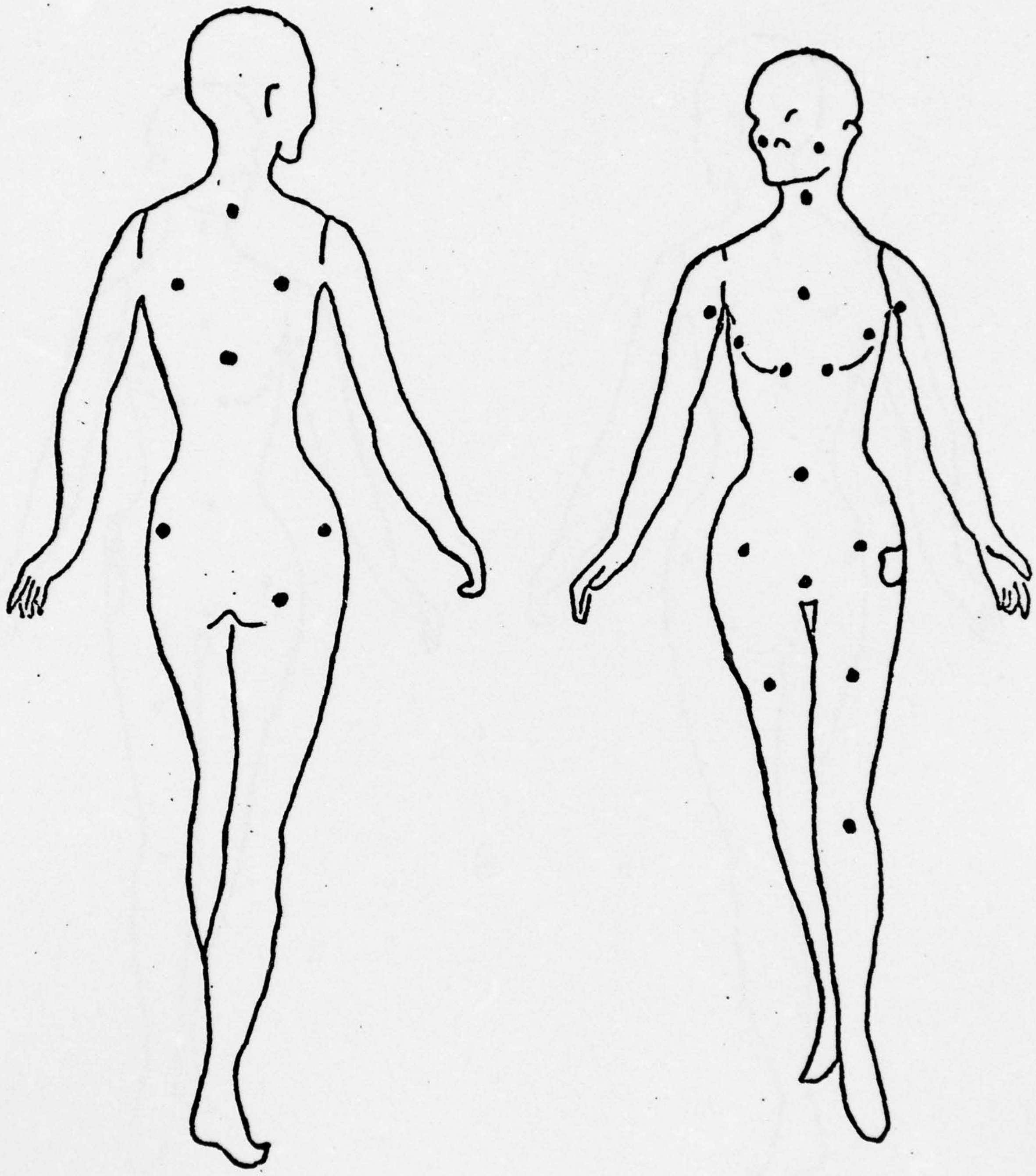
Ignition: Left Coat 6" From Hem

Outfit: 75/25 Polyester/Wool Skirt and Jacket
100% PE Bodysuit 100% Wool Coat

Time: 15 seconds

Burn I.D. No.: 6-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

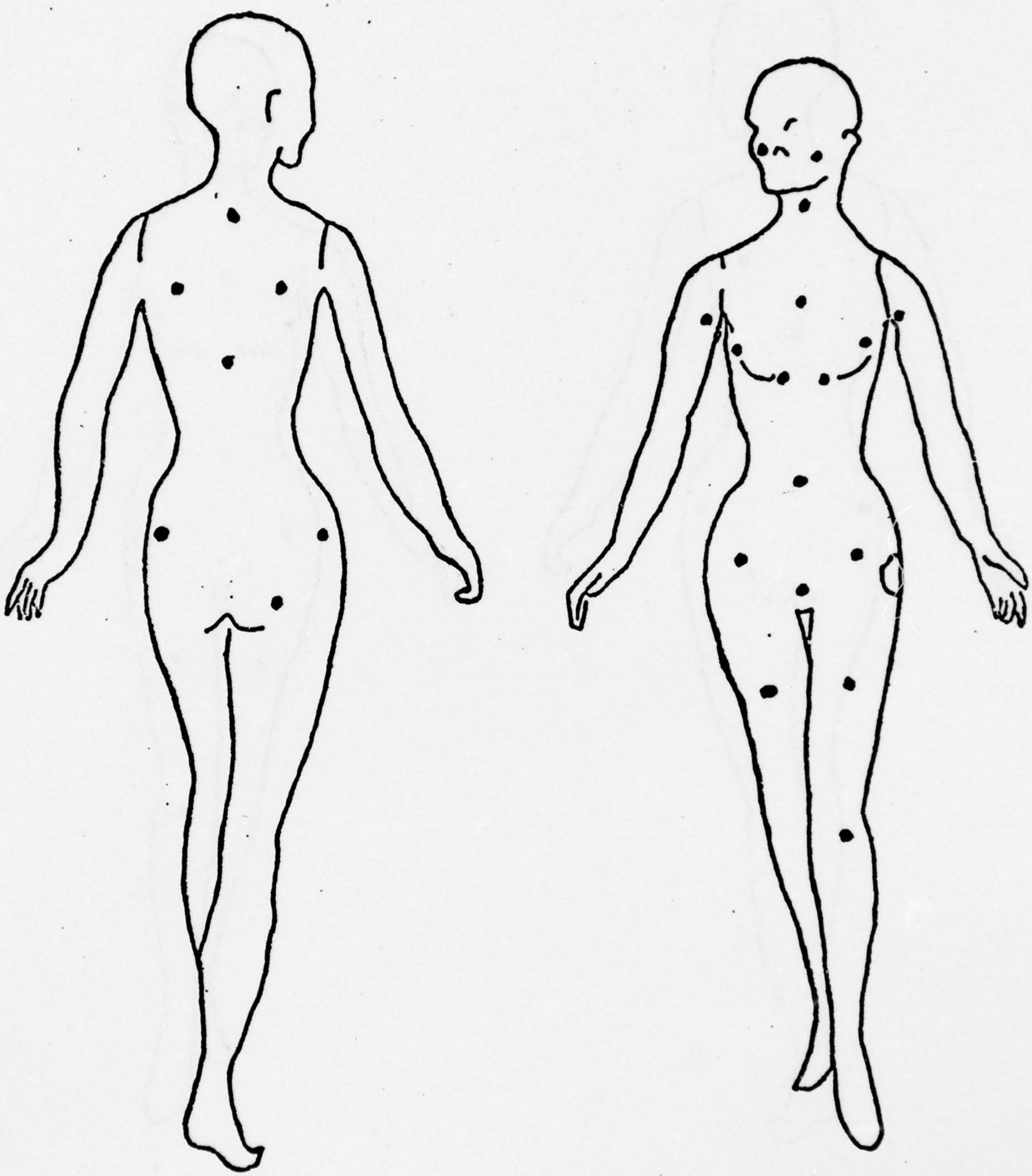
Ignition: Left Coat 6" From Hem

Outfit: 75/25 Polyester/Wool Skirt and Jacket
100% PE Bodysuit 100% Wool Coat

Time: 30 seconds

Burn I.D. No.: 6-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

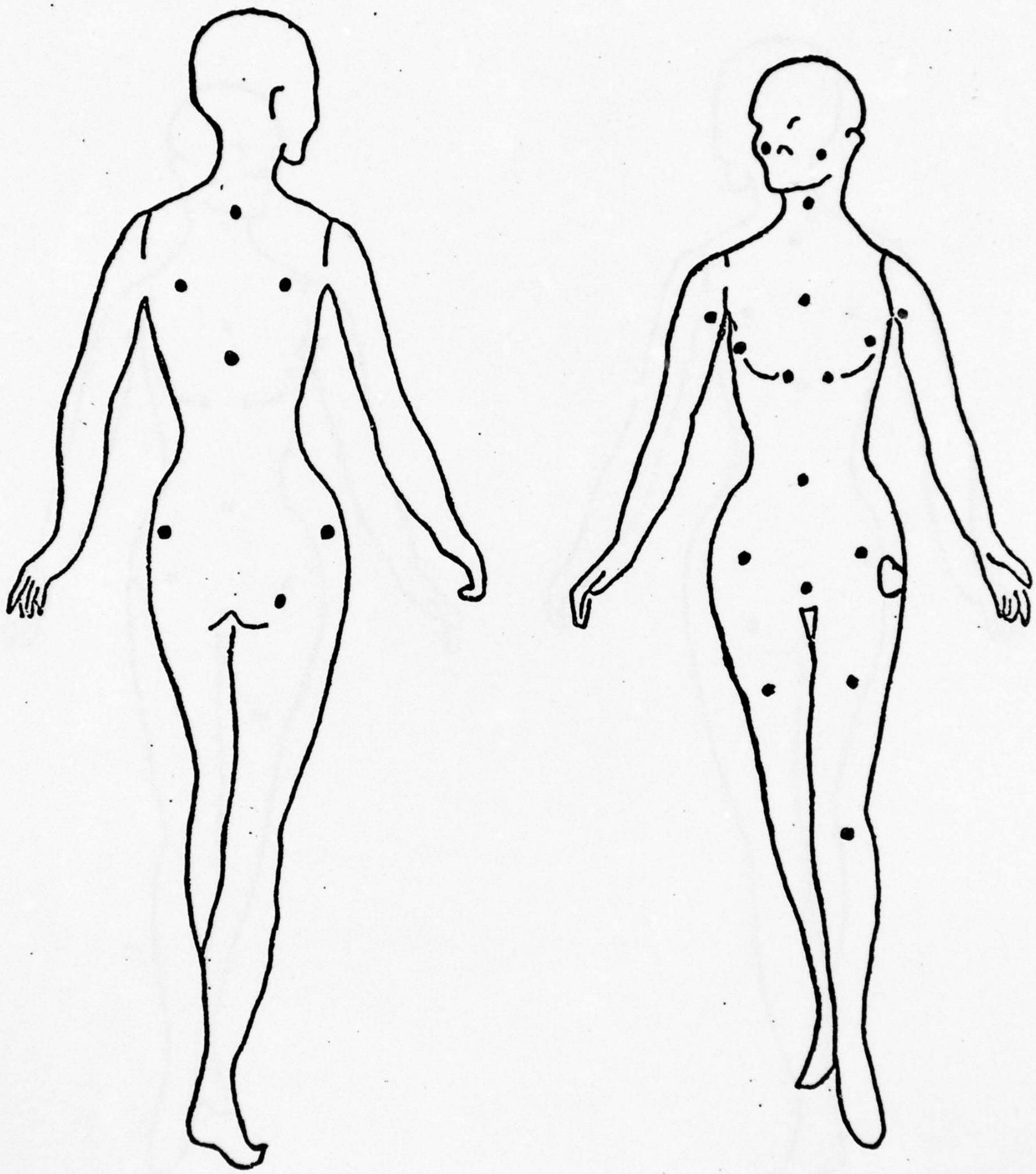


Airline No.: 1 Ignition: Left Coat 6" From Hem

Outfit: 75/25 Polyester/Wool Skirt and Jacket
100% PE Bodysuit 100% Wool Coat

Time: 45 seconds Burn I.D. No.: 6-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

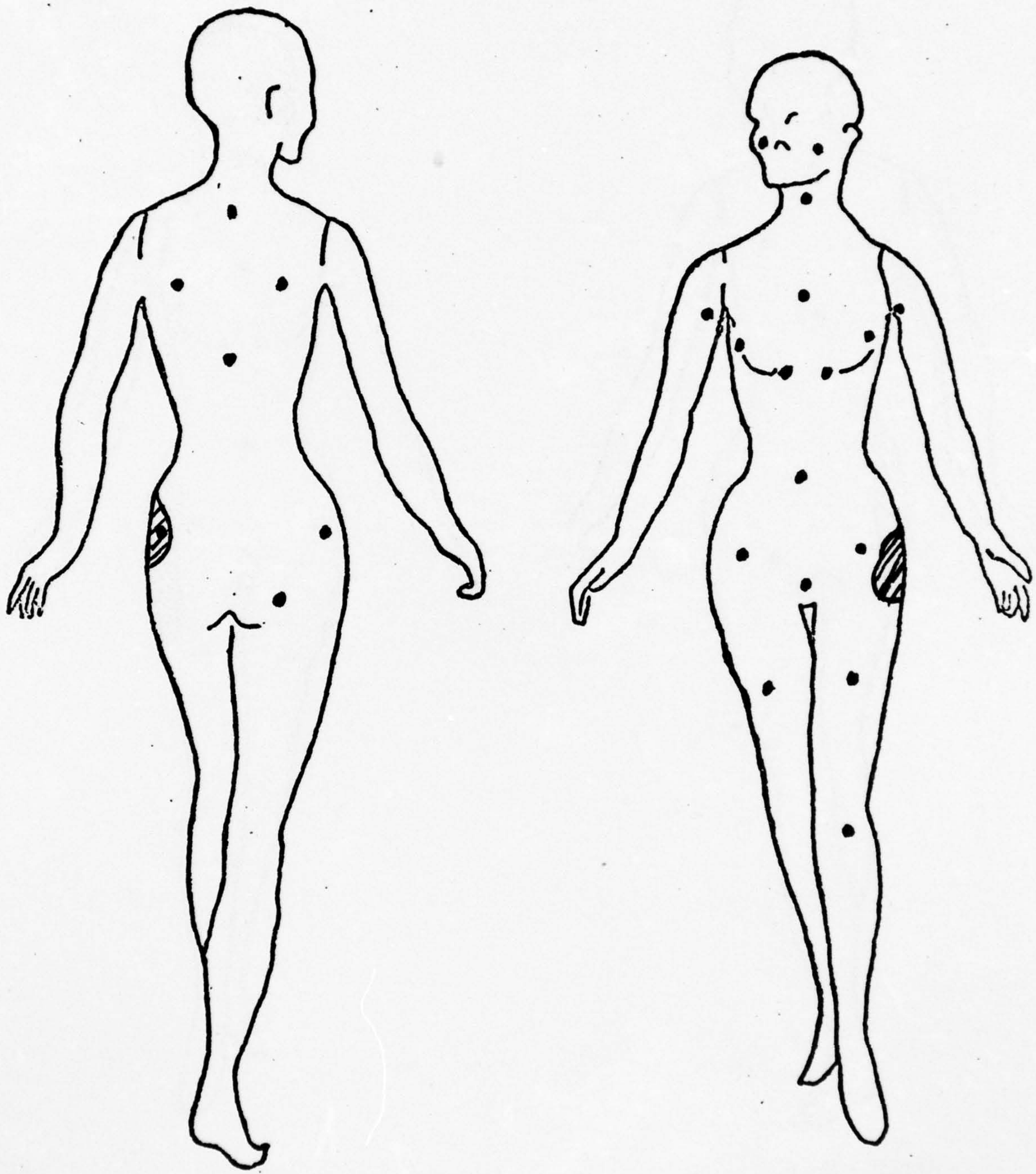


Airline No.: 1 Ignition: Left Coat 6" From Hem

Outfit: 75/25 Polyester/Wool Skirt and Jacket
100% PE Bodysuit 100% Wool Coat

Time: 60 seconds Burn I.D. No.: 6-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

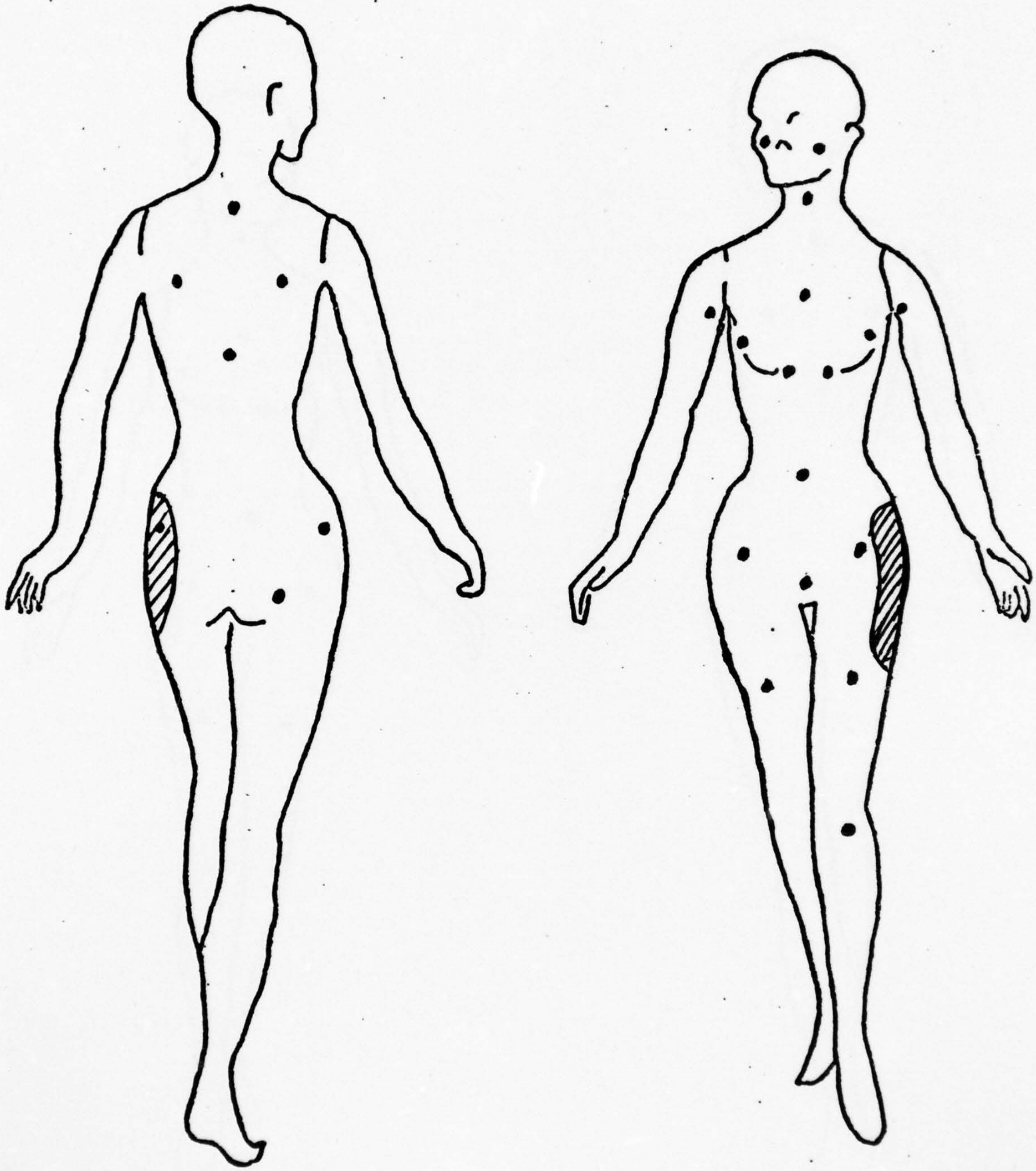
Ignition: Left Skirt 6" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit

Time: 15 seconds

Burn I.D. No.: 6-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

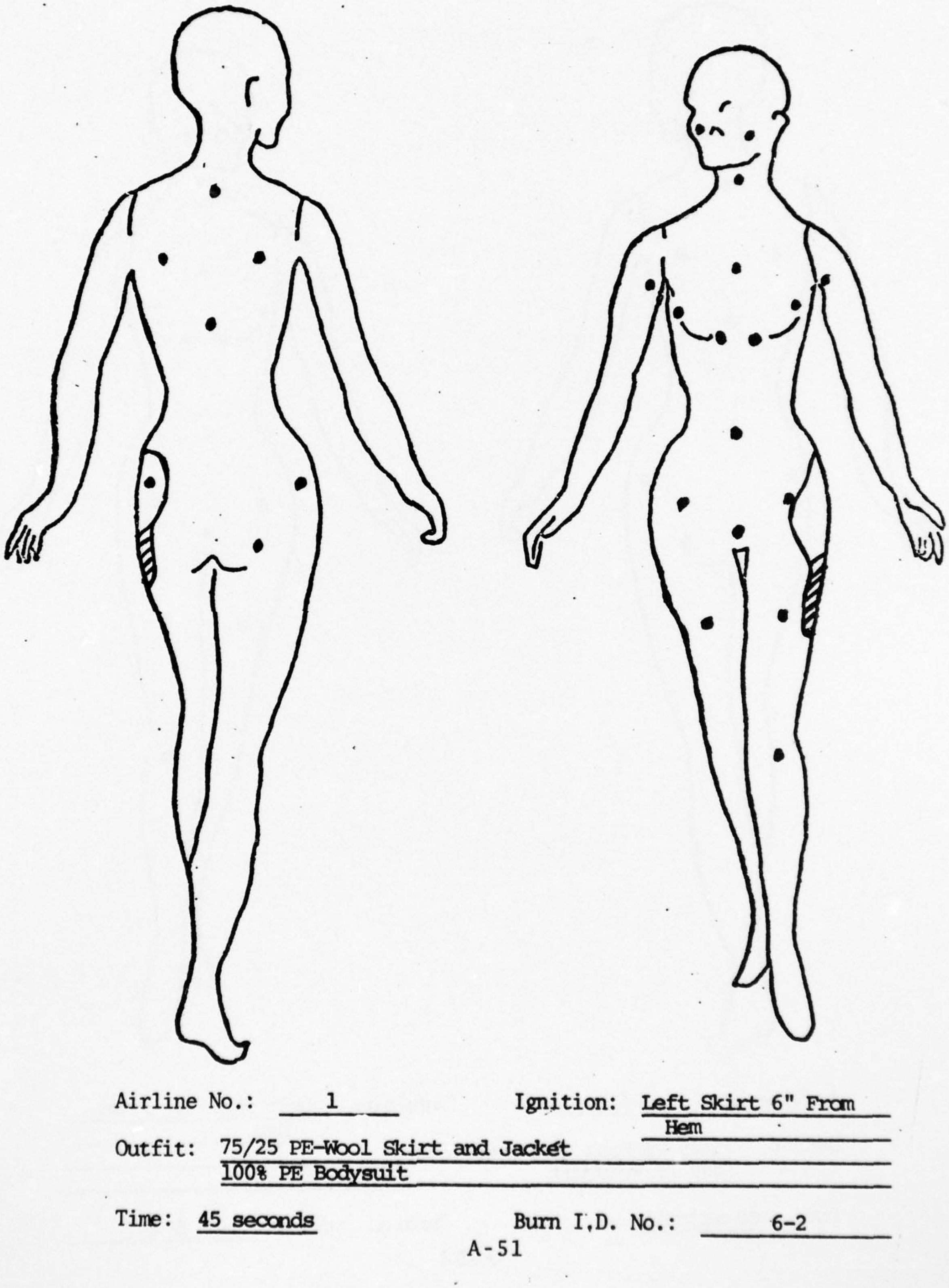
Ignition: Left Skirt 6" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket. 100% PE Bodysuit

Time: 30 seconds

Burn I.D. No.: 6-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

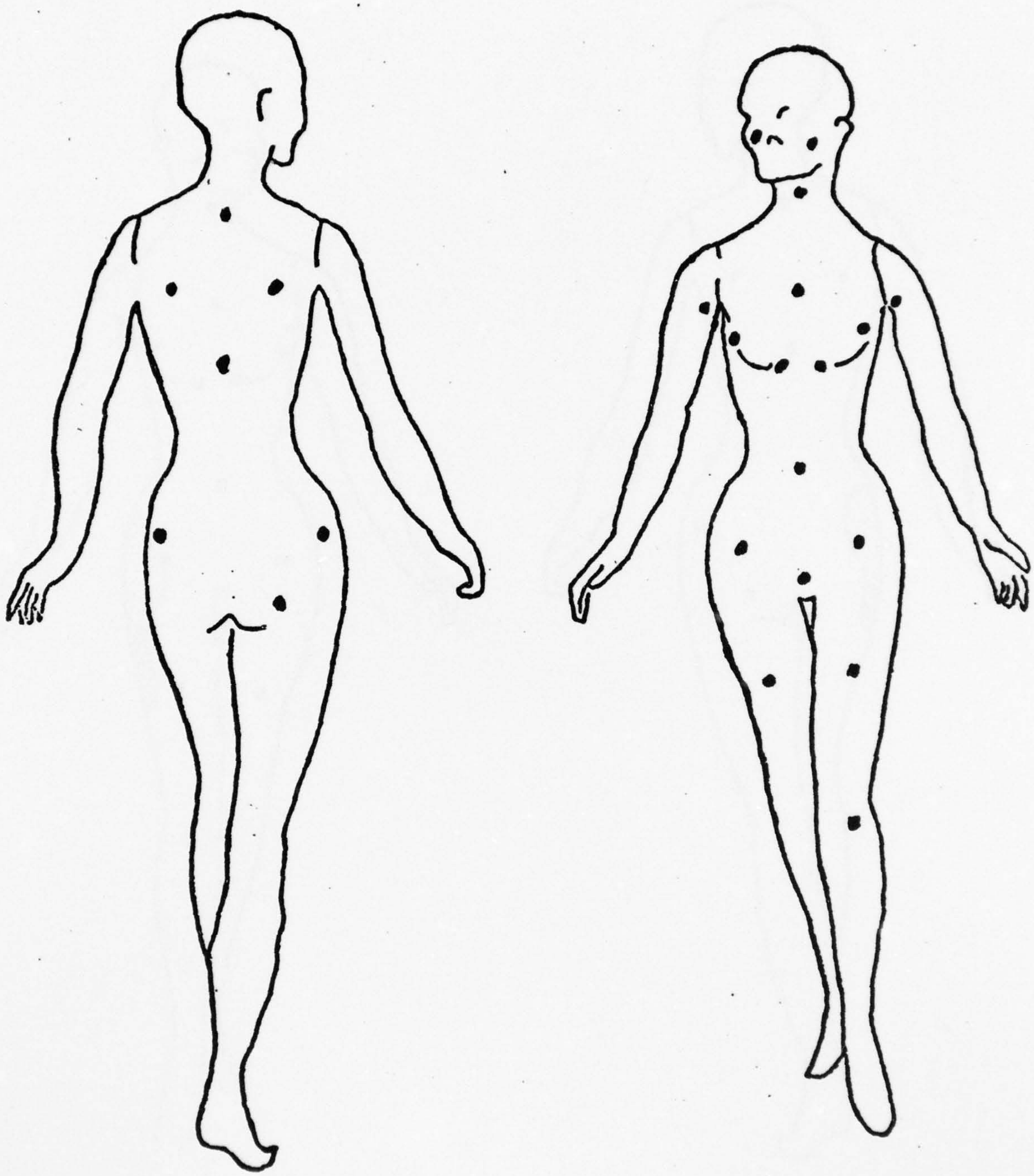
Ignition: Left Skirt 6" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit

Time: 45 seconds

Burn I.D. No.: 6-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

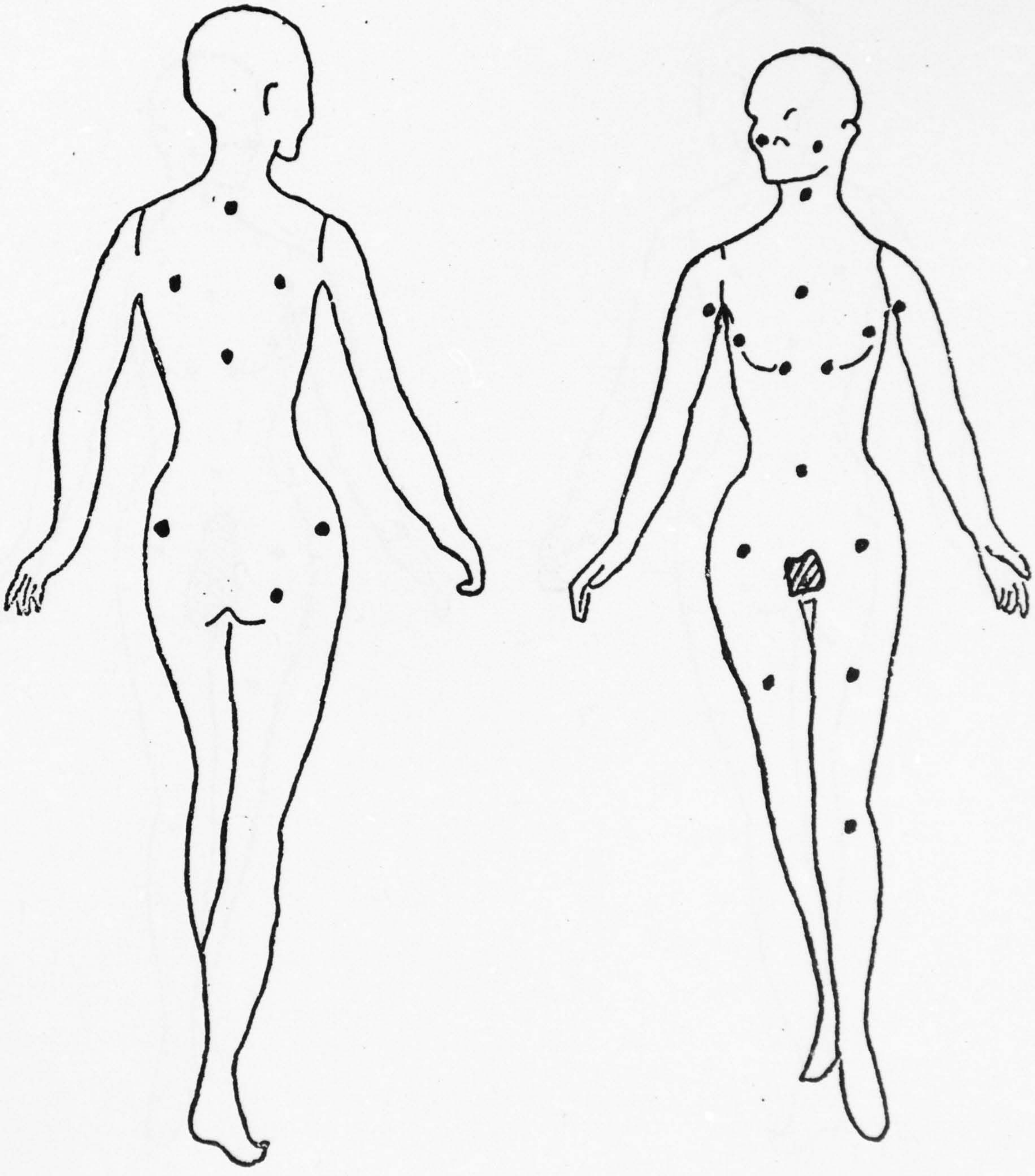
Ignition: Left Skirt 6" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit

Time: 60 seconds

Burn I.D. No.: 6-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

Ignition: Apron Front 3" From Hem

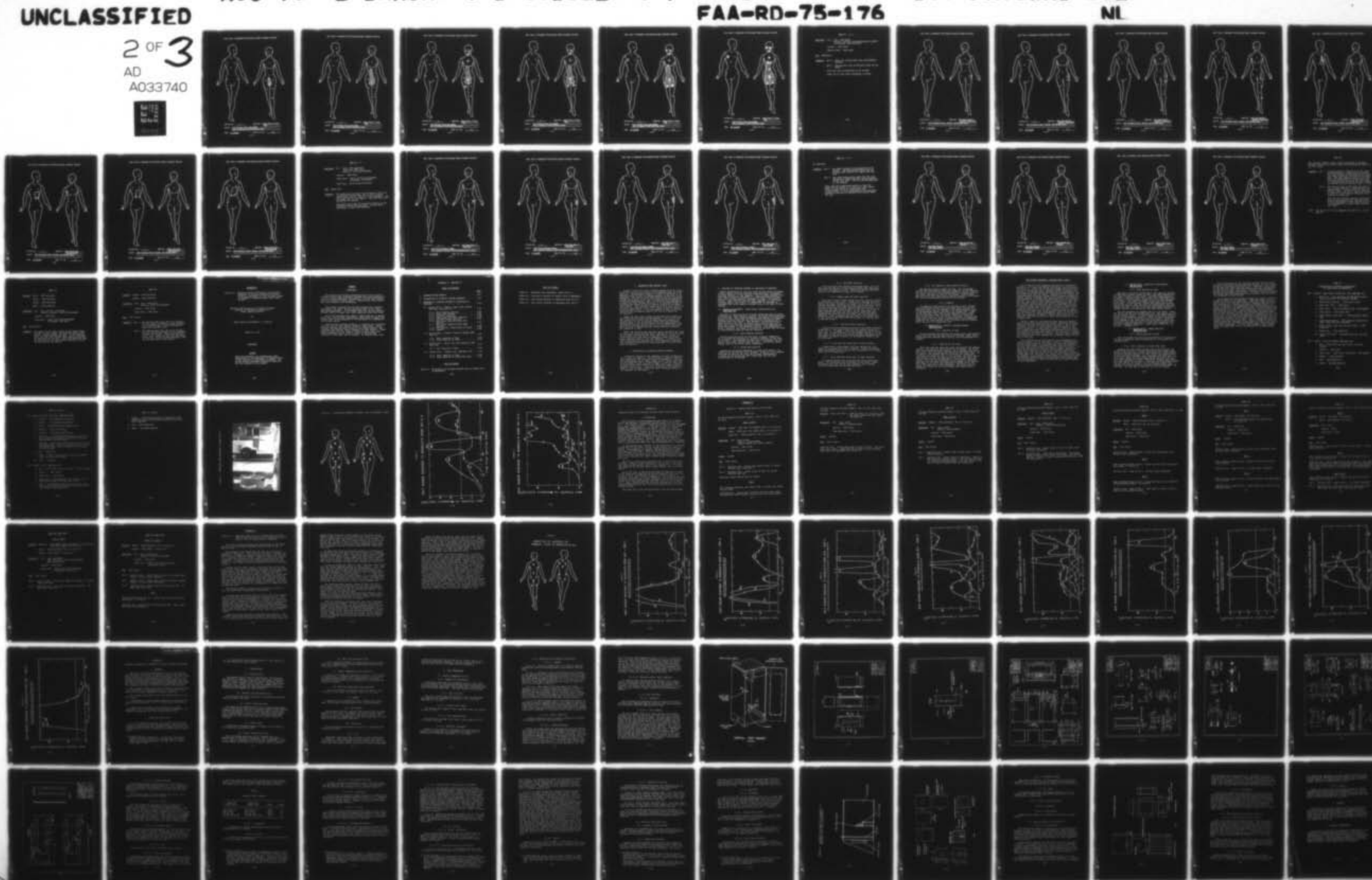
Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit 50/50 PE-Cotton Apron

Time: 15 seconds

Burn I.D. No.: 6-3

AD-A033 740 NATIONAL BUREAU OF STANDARDS WASHINGTON D C F/G 6/17
DEVELOPMENT OF A PROPOSED FLAMMABILITY STANDARD FOR COMMERCIAL --ETC(U)
AUG 76 E BRAUN, V B COBBLE, J F KRASNY DOT-FA75WAI-502
UNCLASSIFIED FAA-RD-75-176 NL

2 OF 3
AD
A033740



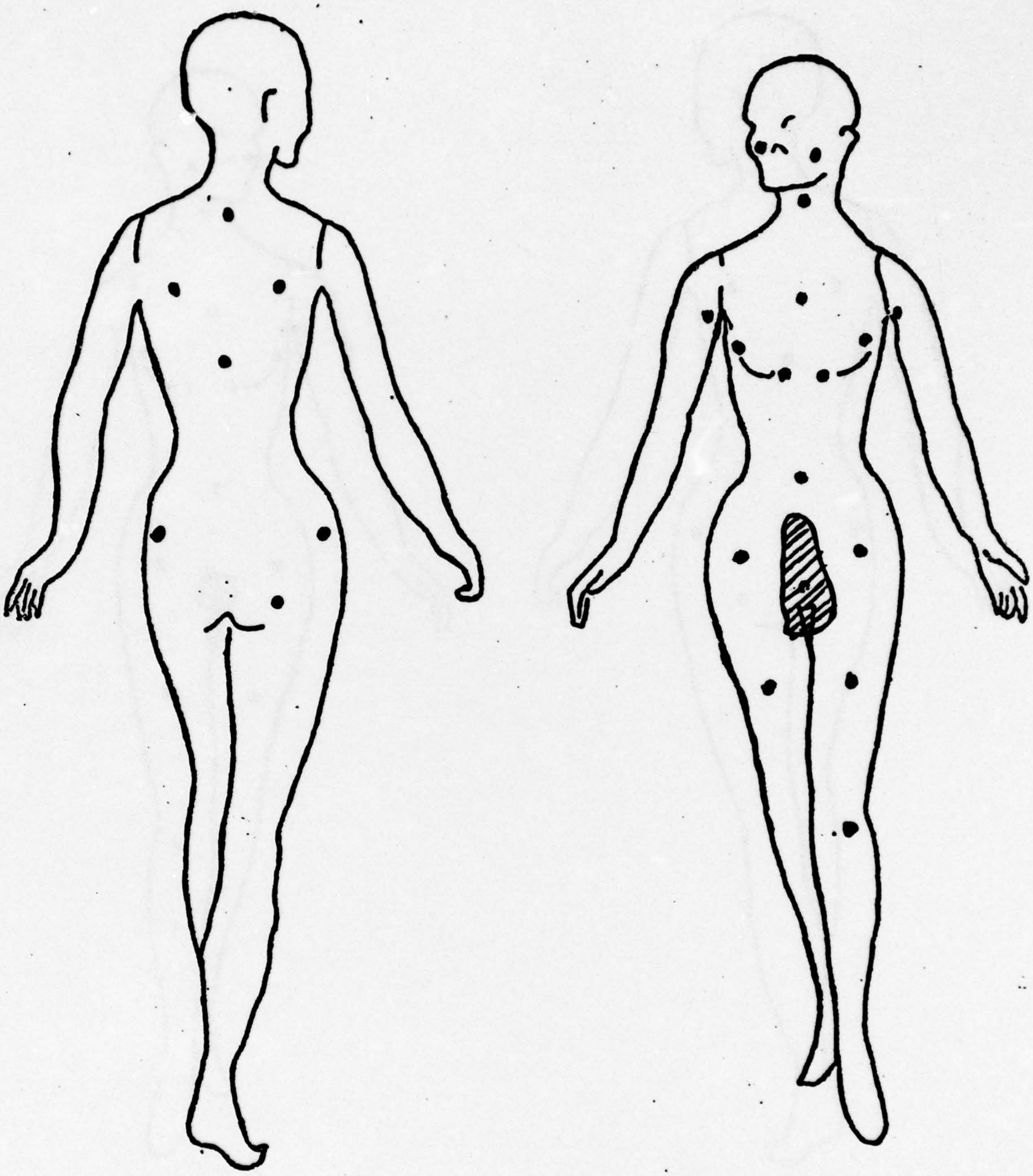
SIFIED

2 OF 3

AD
A033740

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

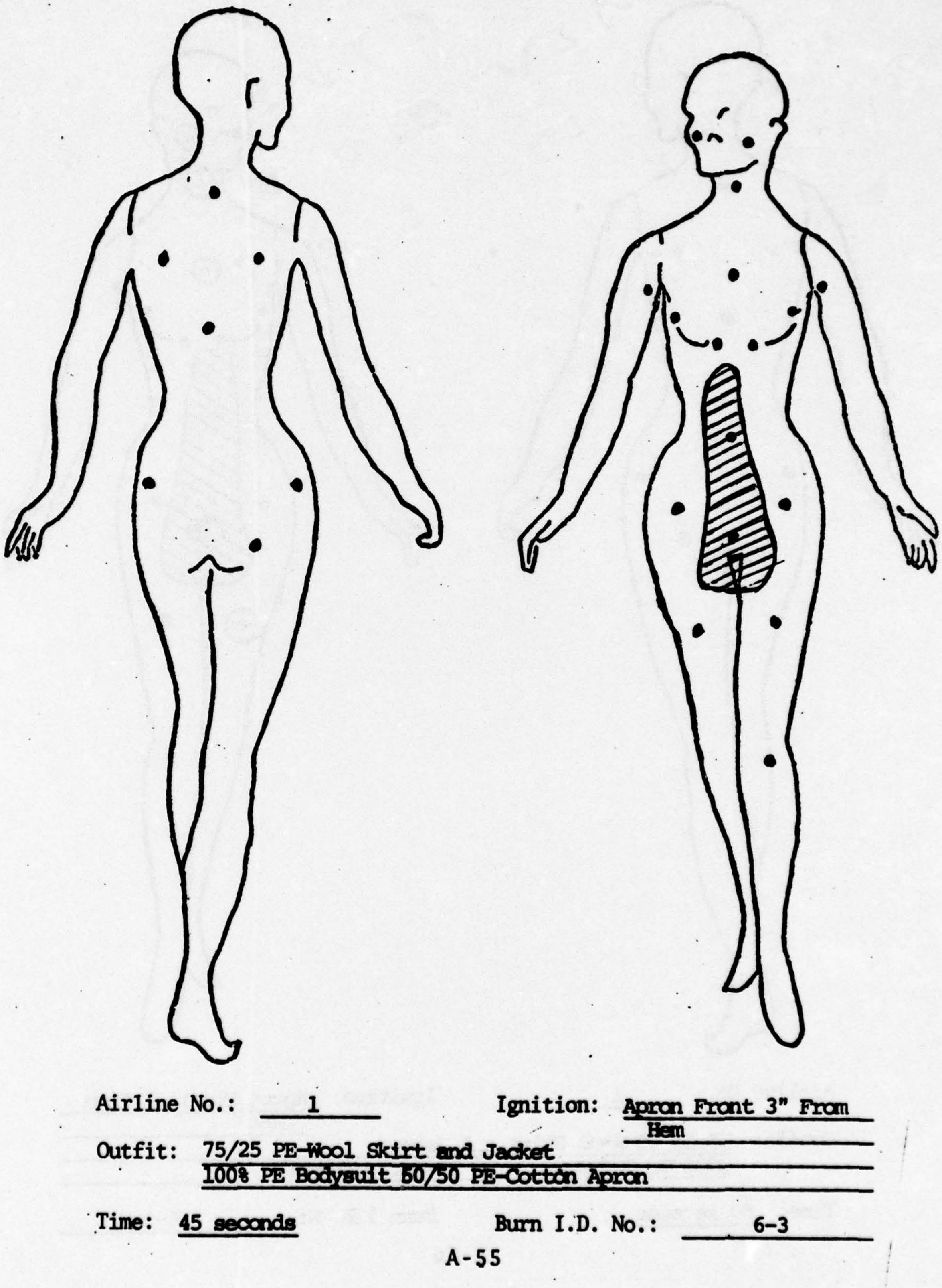
Ignition: Apron Front 3" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit 50/50 PE-Cotton Apron

Time: 30 seconds

Burn I.D. No.: 6-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms

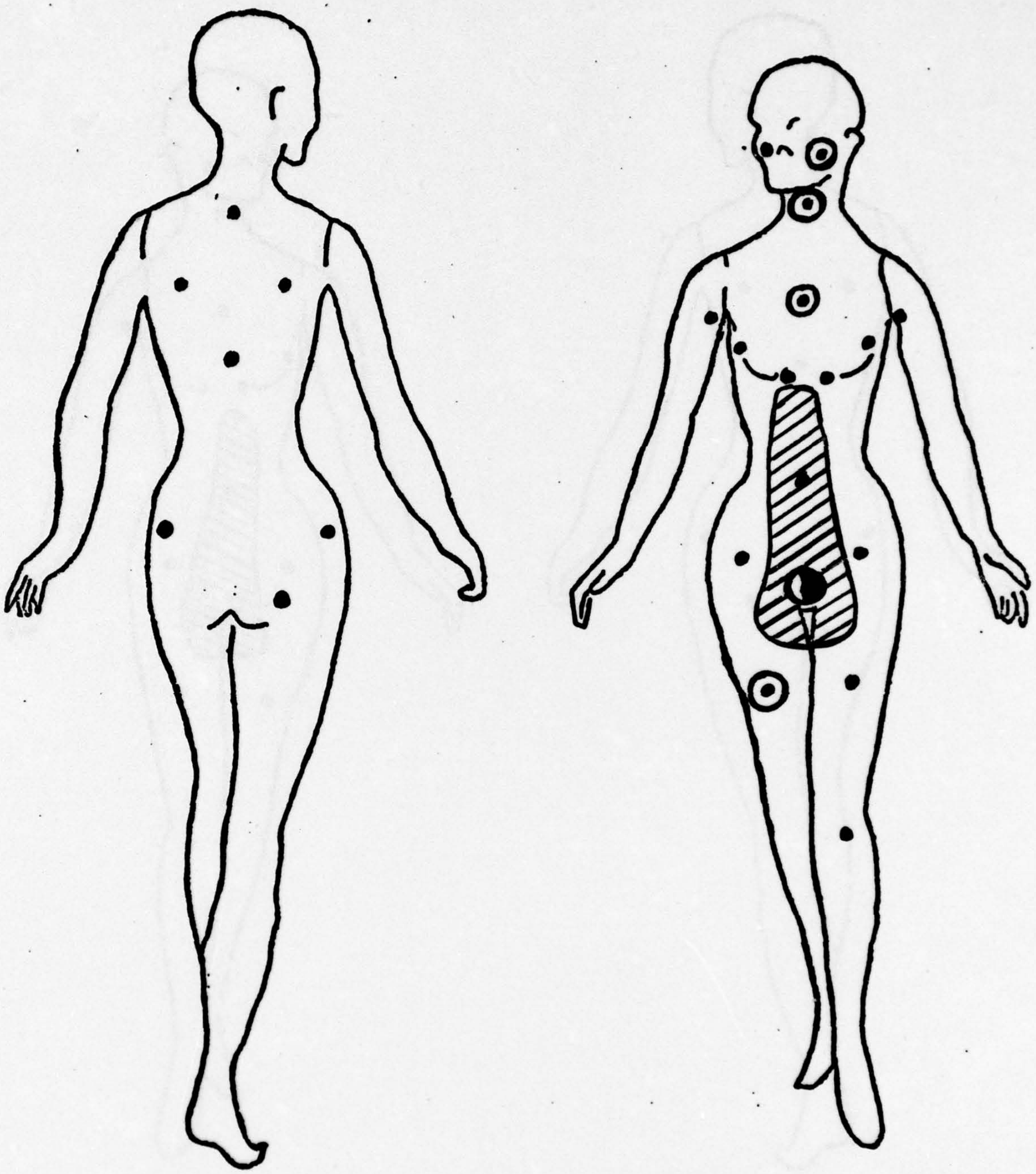


Airline No.: 1 Ignition: Apron Front 3" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit 50/50 PE-Cotton Apron

Time: 45 seconds Burn I.D. No.: 6-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms

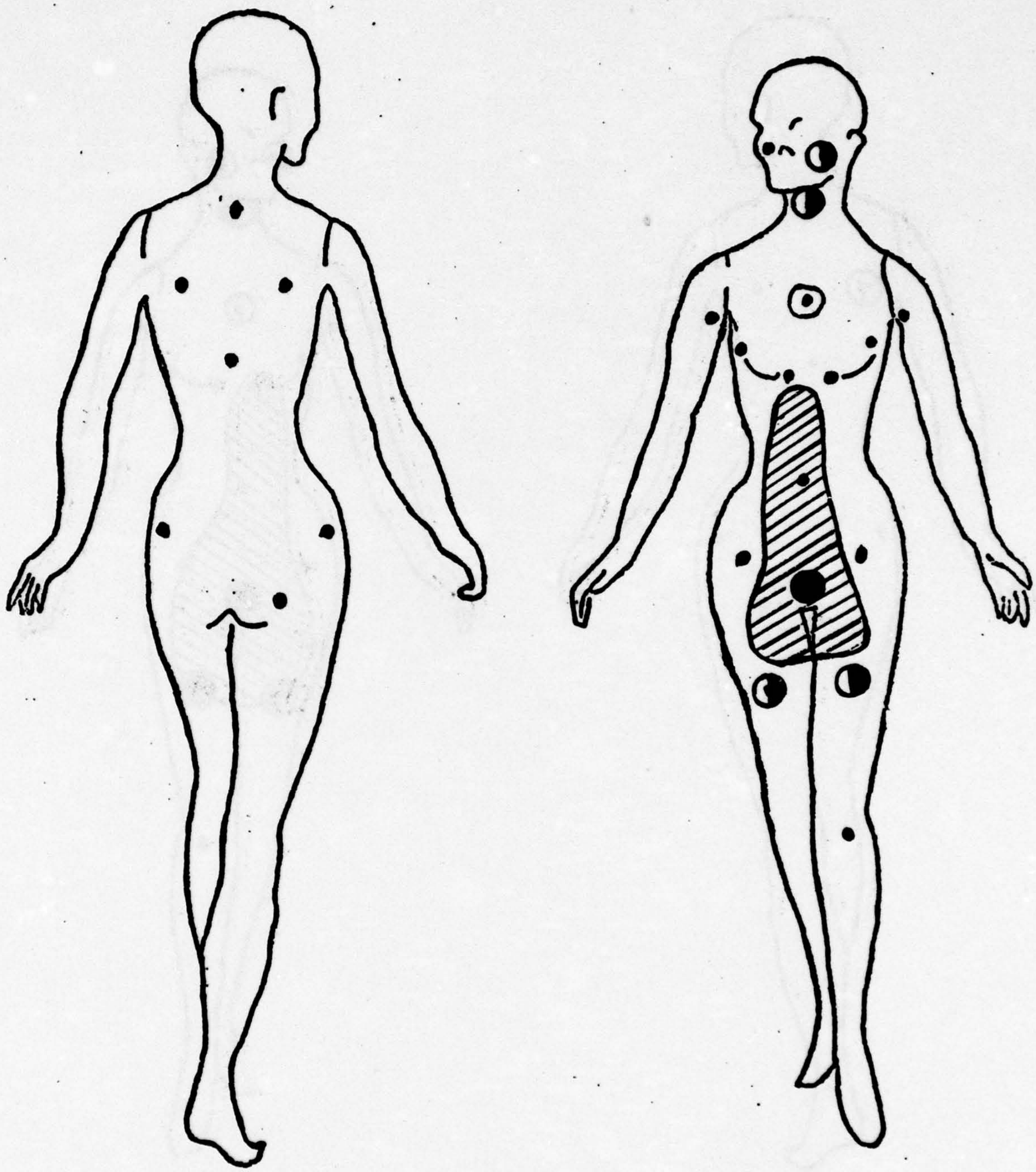


Airline No.: 1 Ignition: Apron Front 3" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit 50/50 PE-Cotton Apron

Time: 60 seconds Burn I.D. No.: 6-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms

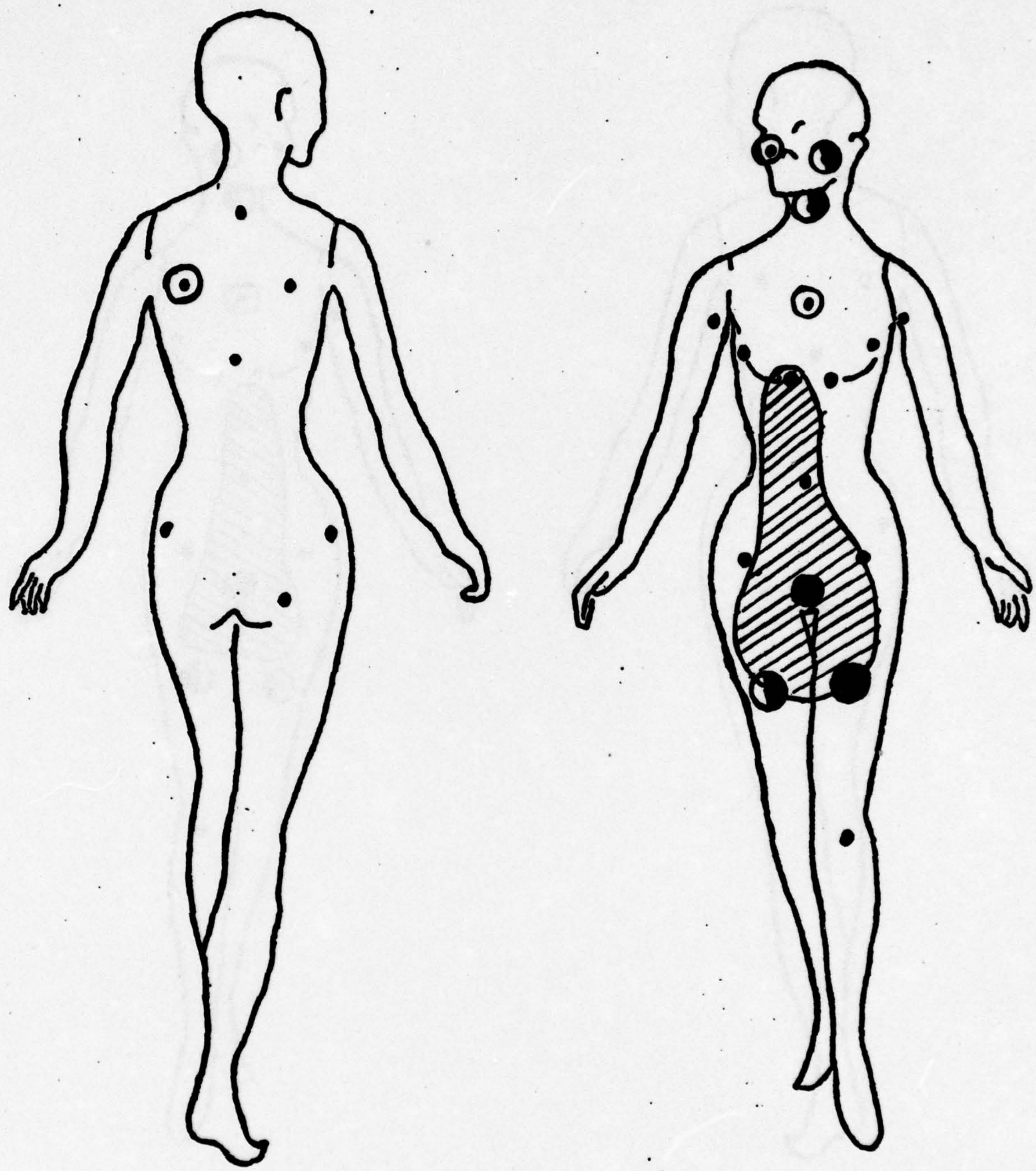


Airline No.: 1 Ignition: Apron Front 3" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit 50/50 PE-Cotton Apron

Time: 75 seconds Burn I.D. No.: 6-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

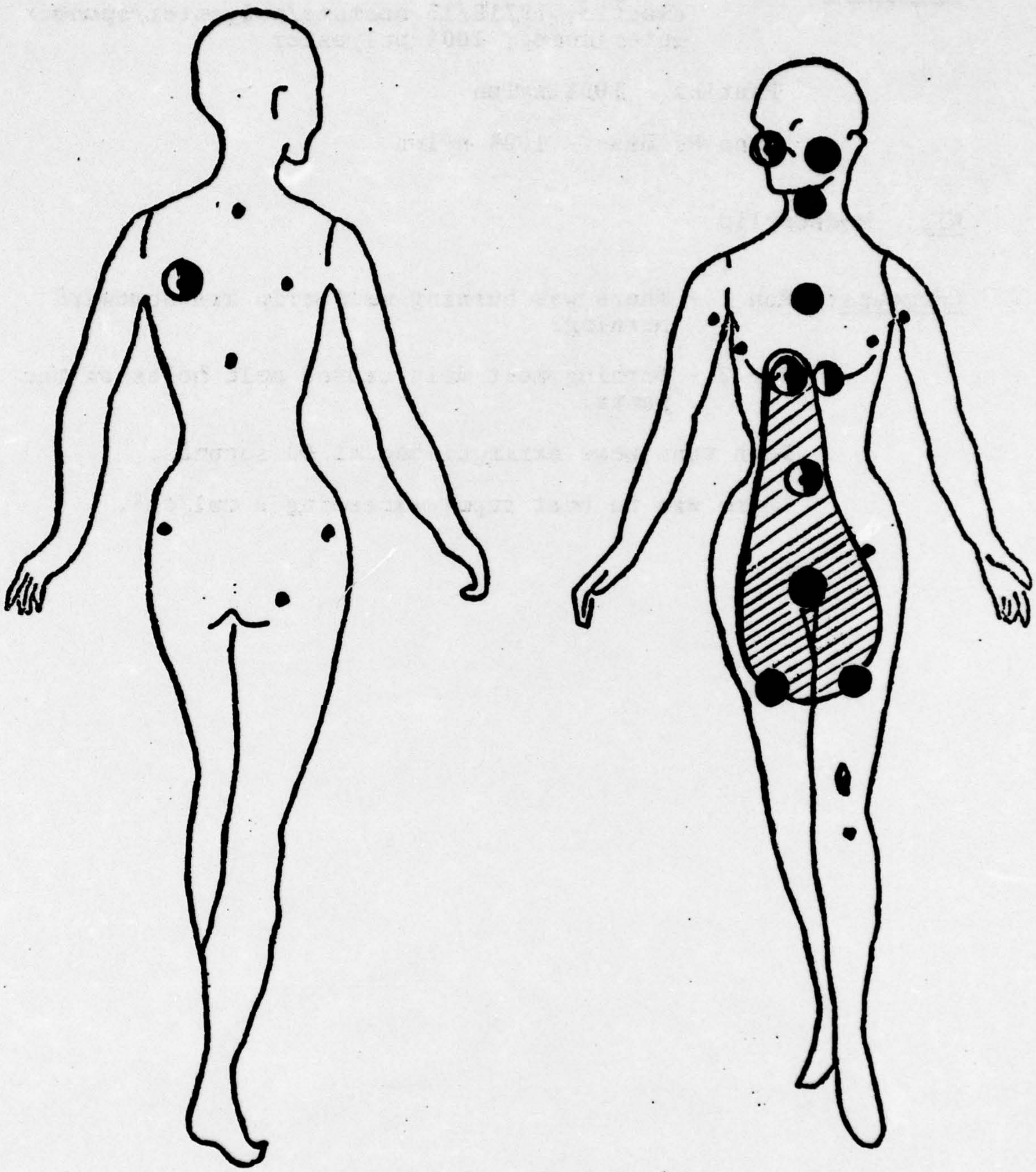
Ignition: Apron Front 3" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit 50/50 PE-Cotton Apron

Time: 90 seconds

Burn I.D. No.: 6-3

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1 Ignition: Apron Front 3" From Hem

Outfit: 75/25 PE-Wool Skirt and Jacket
100% PE Bodysuit 50/50 PE-Cotton Apron

Time: 120 seconds Burn I.D. No.: 6-3

BURN #7 - 1, 2

Underwear: Bra - lace, 100% nylon
elastic, 69/18/13 acetate/polyester/spandex
interlining, 100% polyester

Panties - 100% nylon

Knee-Hi Hose - 100% nylon

Wig: Modacrylic

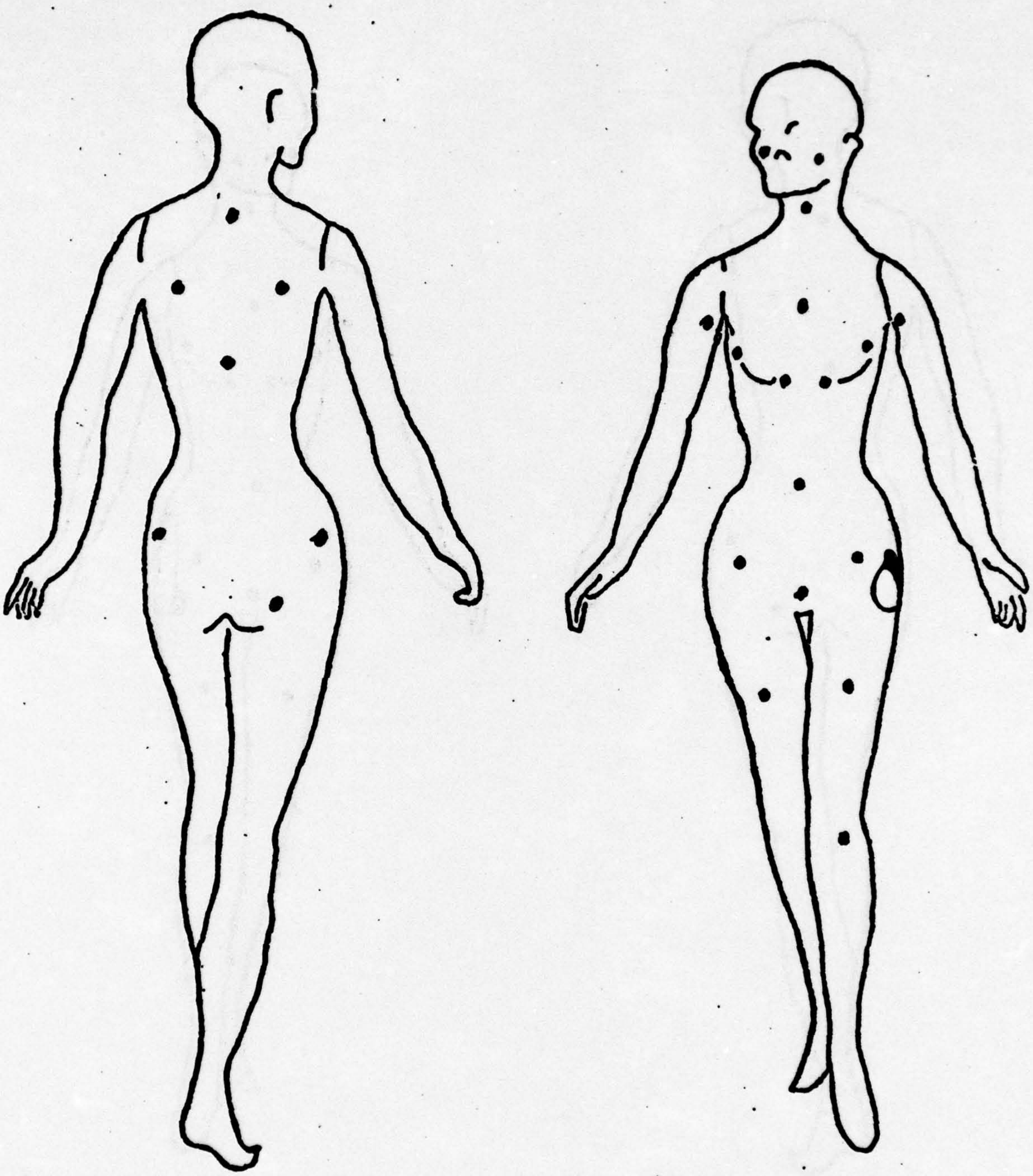
Comments: Run 1 - There was burning melt drip and downward burning.

Run 2 - Burning melt drip caused melt holes on the pants.

Both runs were extinguished at 90 seconds.

There was no heat input exceeding 2 cal/cm^2.

Heat Input to Mannequin From Burning Flight Attendant Uniforms

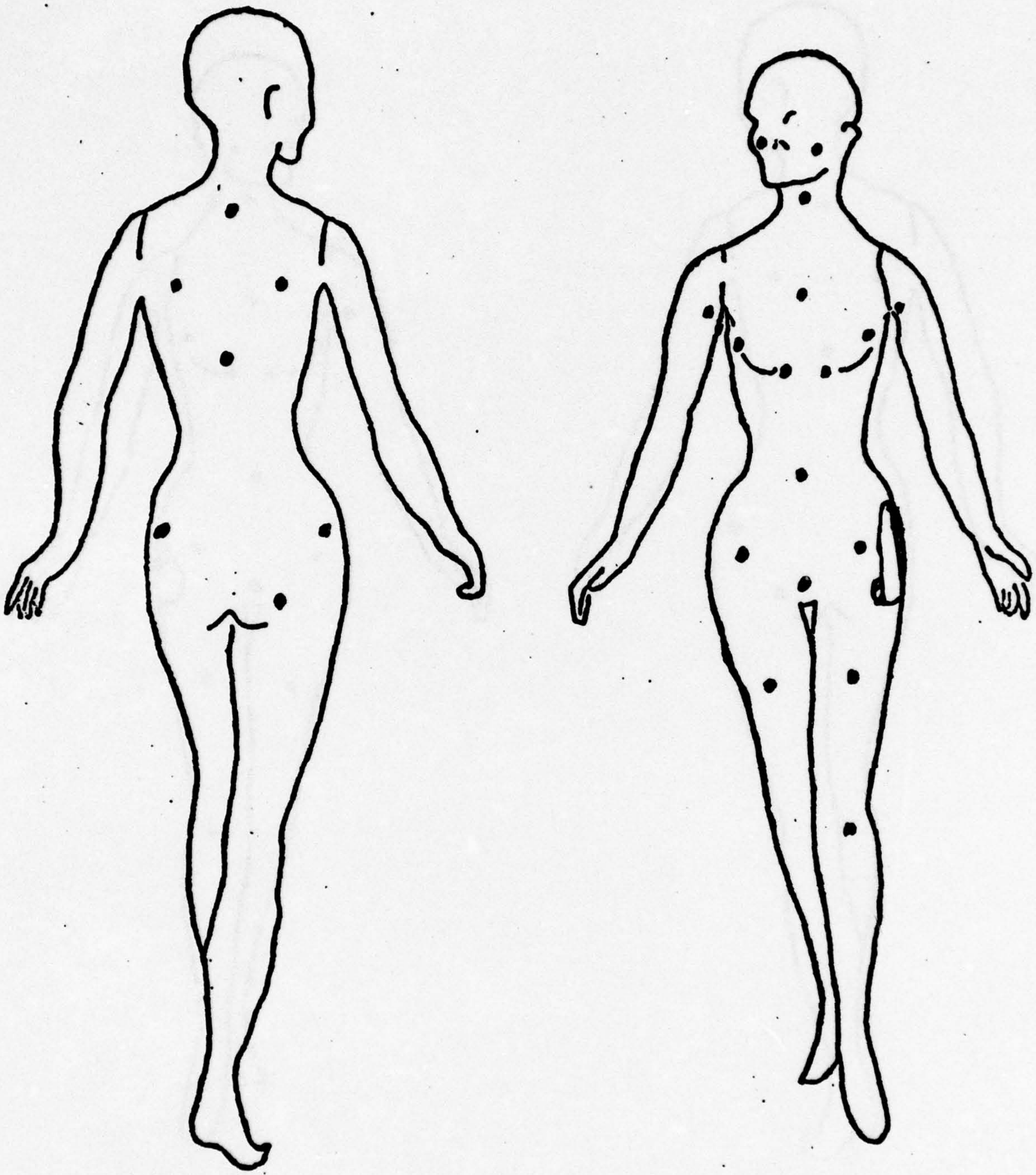


Airline No.: 5   Ignition: Left Side Serving Smock 3" Above Hem

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 15 seconds   Burn I.D. No.: 7-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

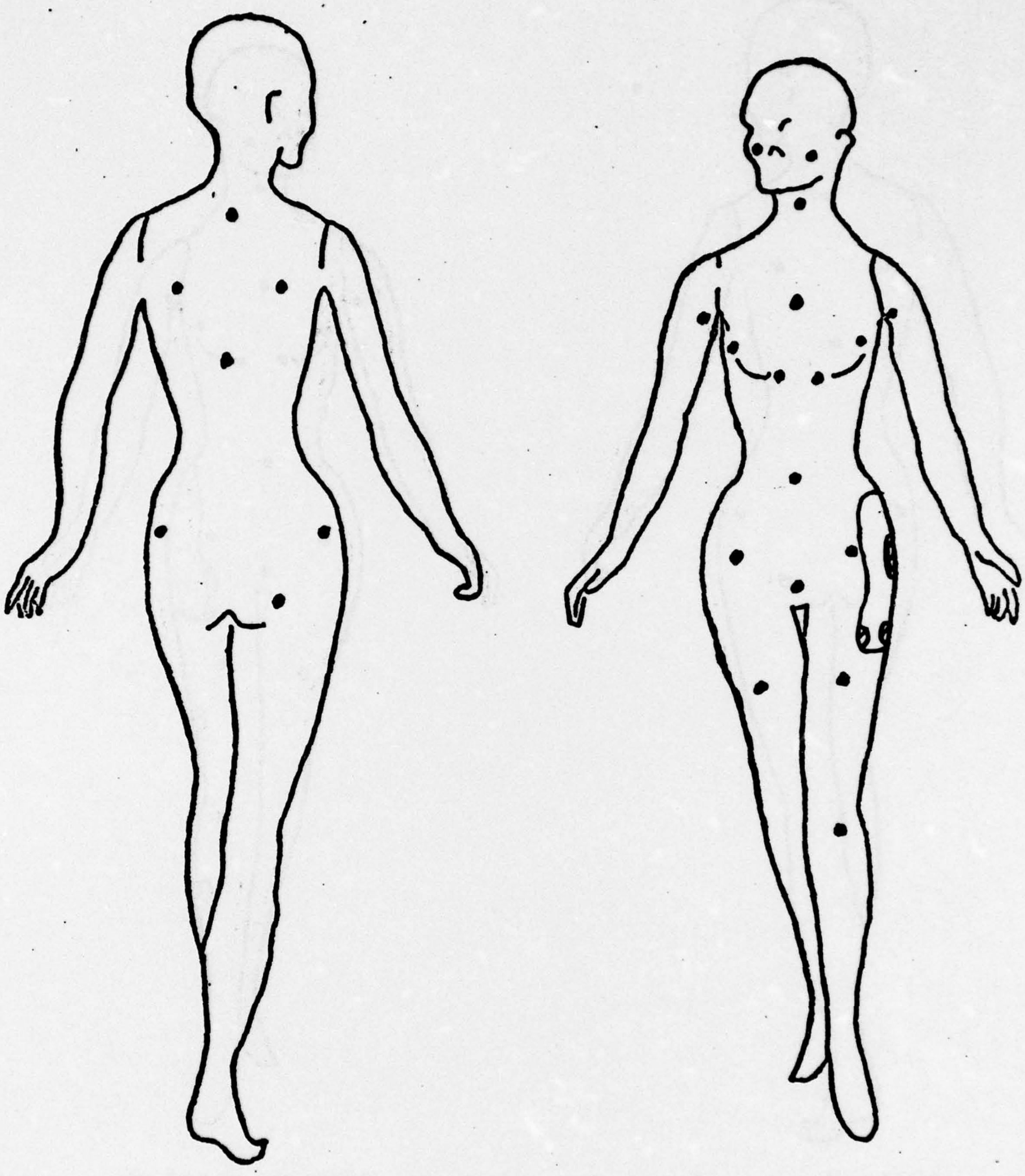


Airline No.: 5 Ignition: Left Side Serving Smock 3" Above Hem

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 30 seconds Burn I.D. No.: 7-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

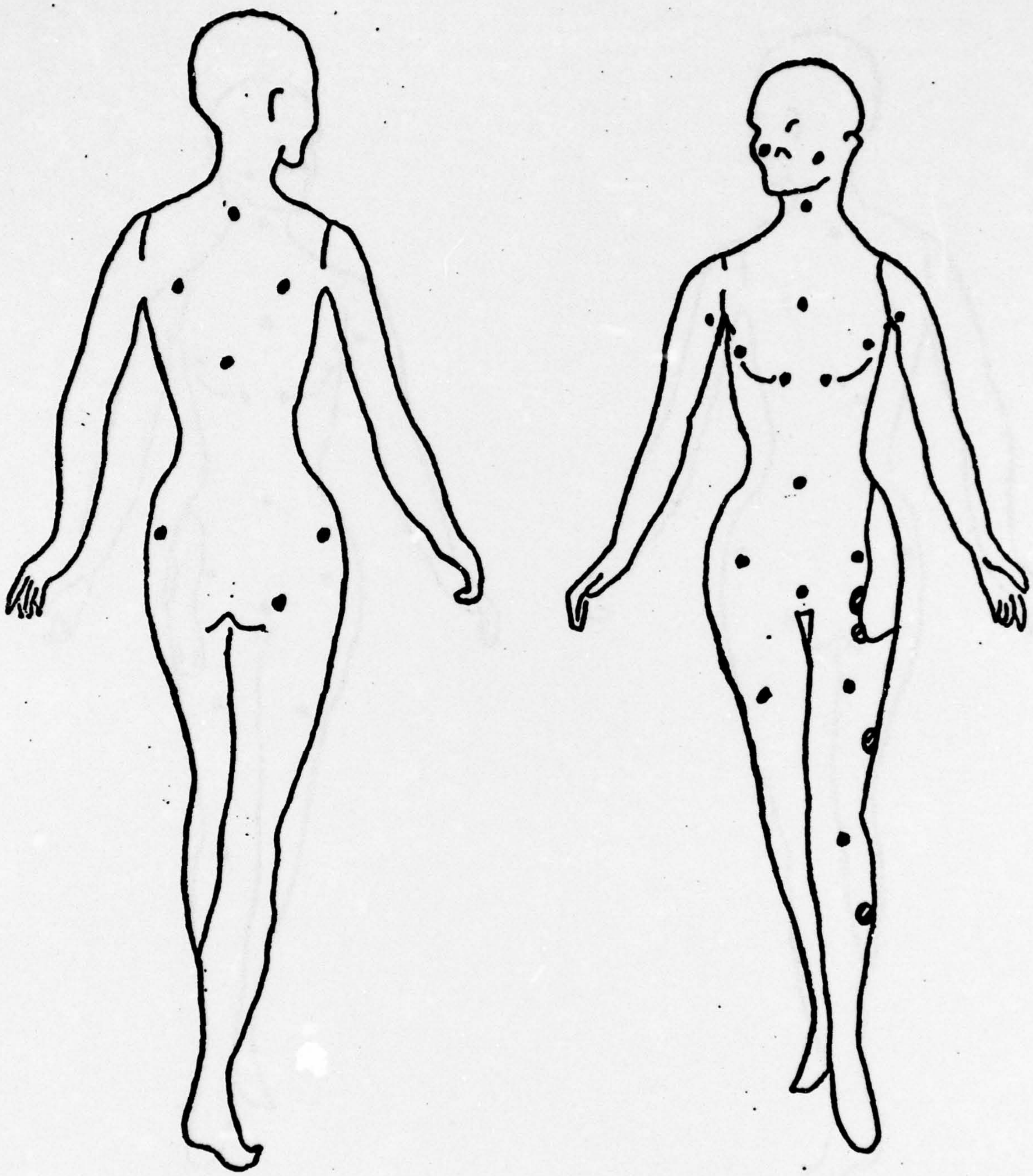


Airline No.: 5 Ignition: Left Side Serving Smock 3" Above Hem

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 45 seconds Burn I.D. No.: 7-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

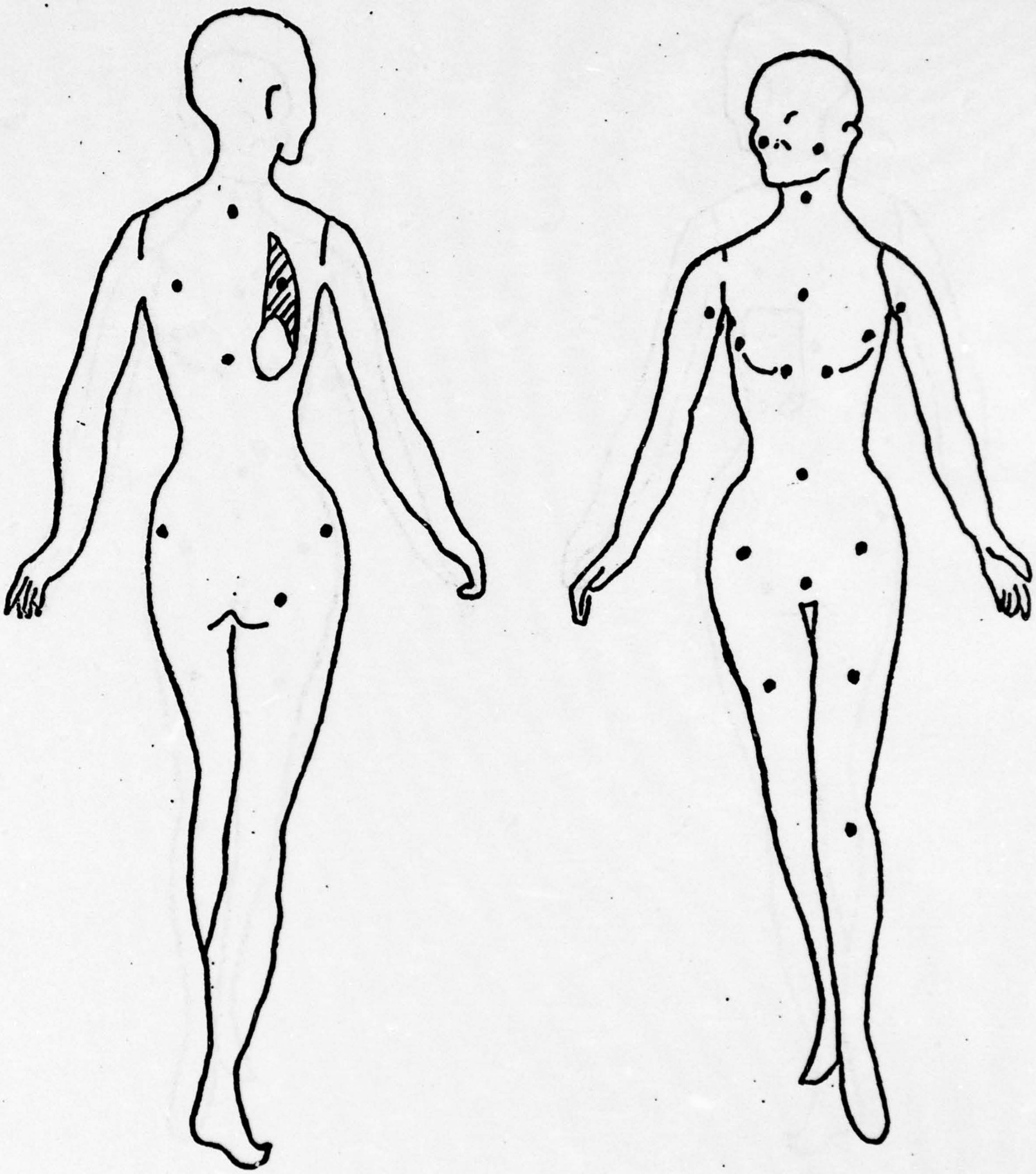


Airline No.: 5 Ignition: Left Side Serving Smock 3" Above Hem

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 60 seconds Burn I.D. No.: 7-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

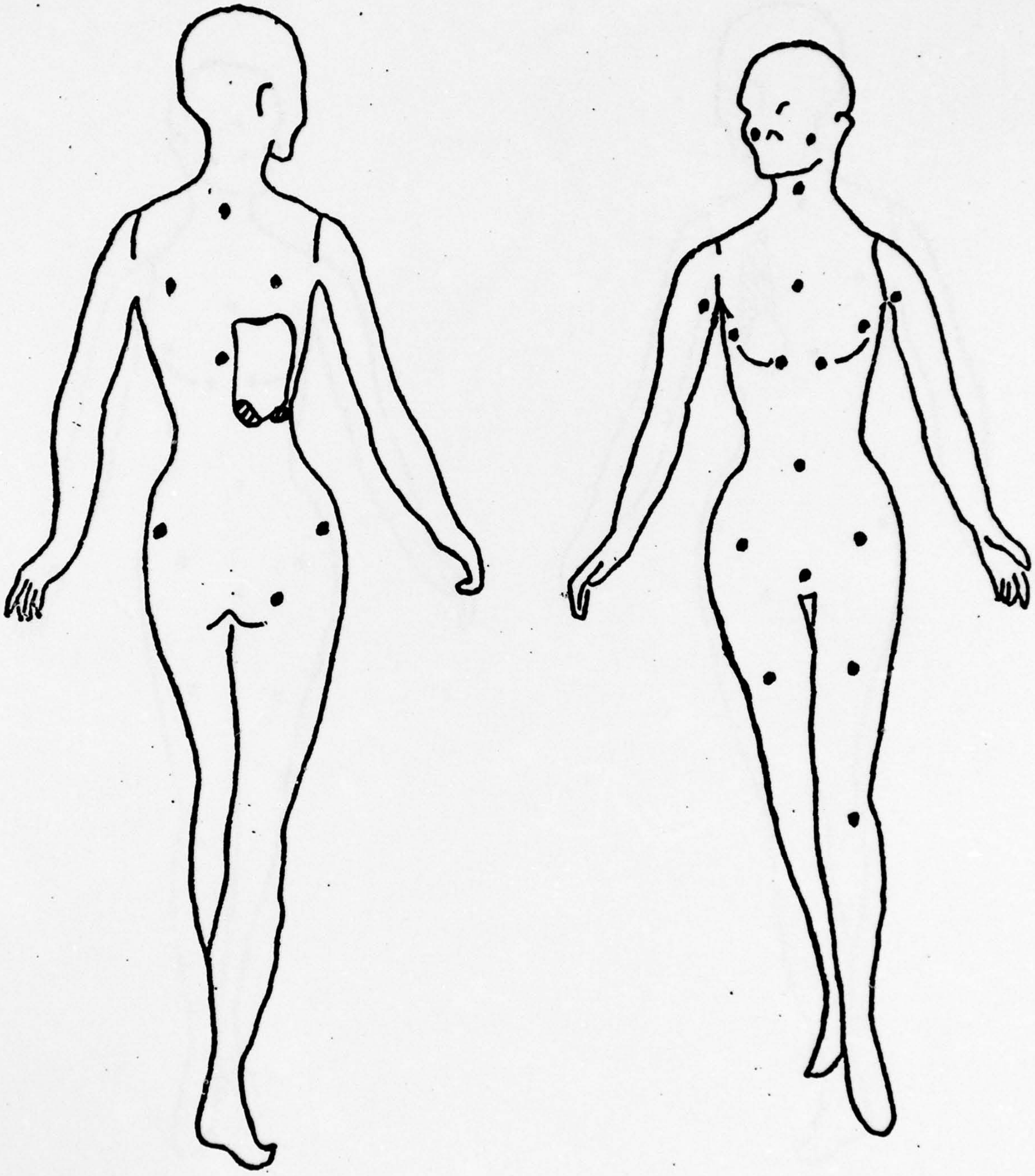


Airline No.: 5 Ignition: Right Lower Back Serving Smock

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 15 seconds Burn I.D. No.: 7-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

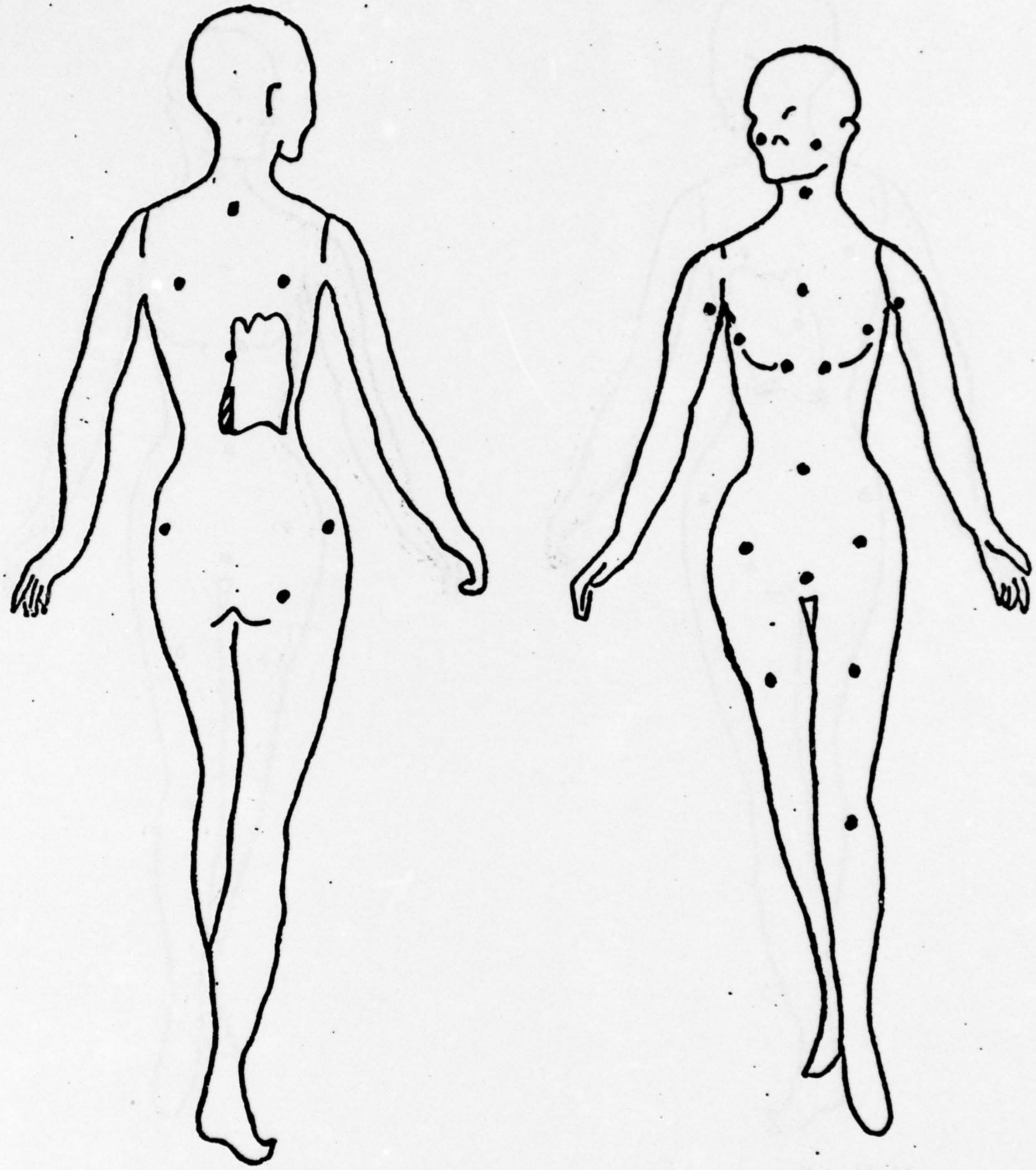


Airline No.: 5 Ignition: Right Lower Back Serving Smock

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 30 seconds Burn I.D. No.: 7-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms

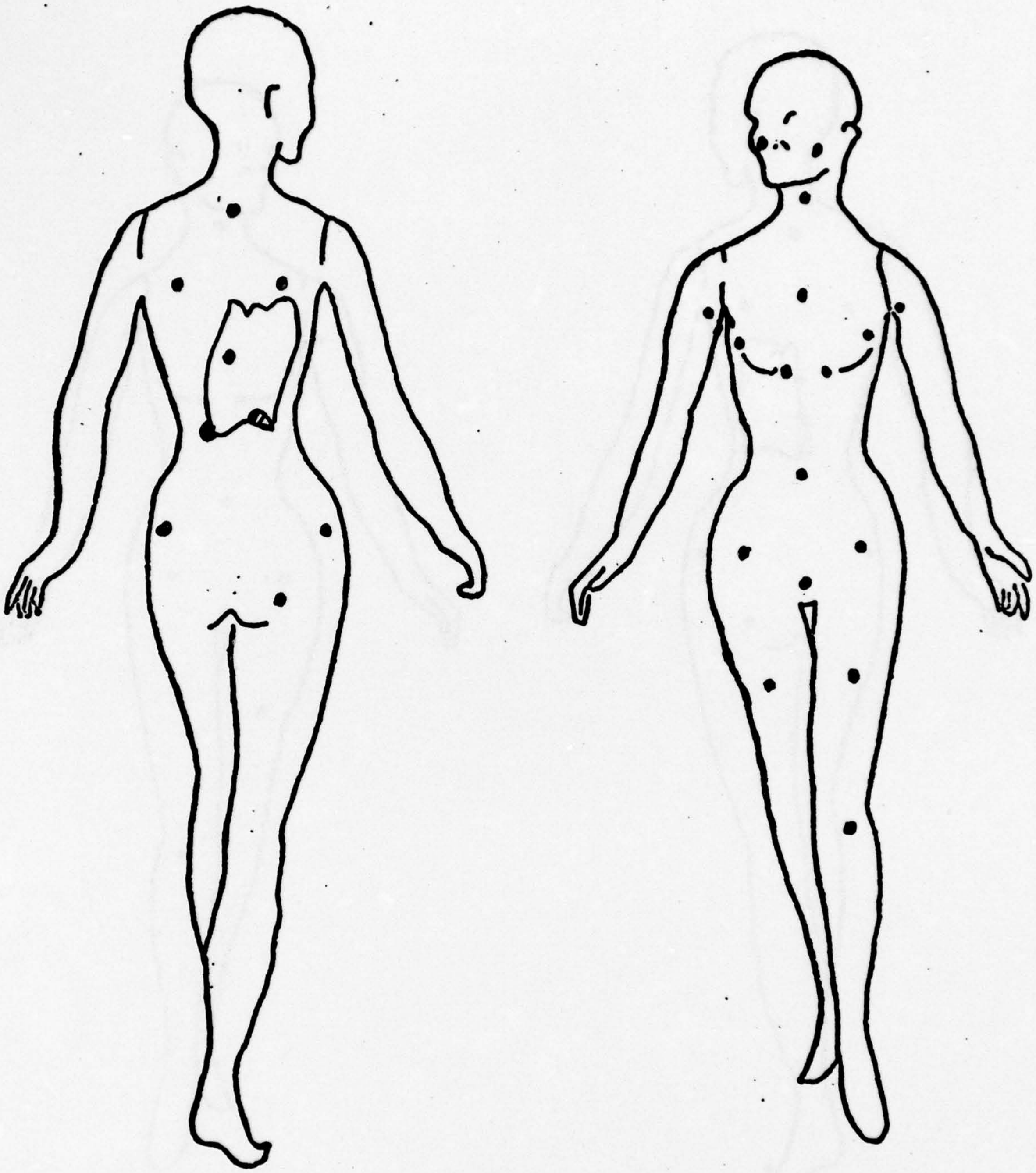


Airline No.: 5 Ignition: Right Lower Back Serving Smock

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 45 seconds Burn I.D. No.: 7-2

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 5

Ignition: Right Lower Back Serving Smock

Outfit: 100% Polyester Pants, Blouse, and Serving Smock

Time: 60 seconds

Burn I.D. No.: 7-2

BURN #8 - 1

Underwear: Bra - lace, 100% polyester
lower cup, 100% nylon
elastic, 77/23 nylon/spandex

Panties - 100% nylon

Panty Hose - panty, 80/20 nylon/spandex
stockings, 100% nylon

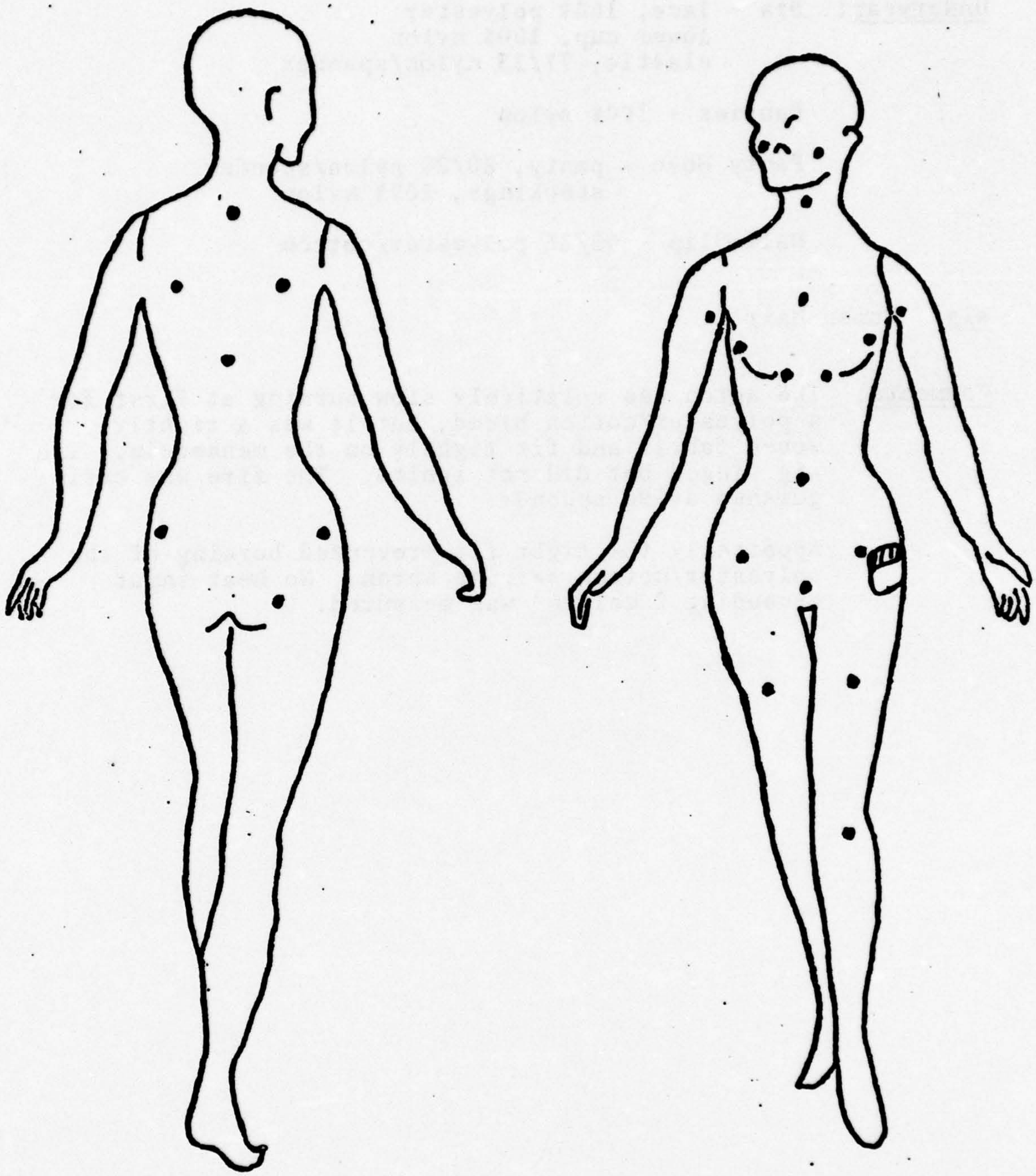
Half-Slip - 65/35 polyester/cotton

Wig: Human Hair

Comments: The apron was relatively slow burning at first for a polyester/cotton blend, but it was a tightly woven fabric and fit tightly on the mannequin. The wig singed but did not ignite. The fire was extinguished at 90 seconds.

Apparently the tight fit prevented burning of the polyester/cotton serving apron. No heat input exceeding 2 cal/cm^2 was measured.

Heat Input to Mannequin From Burning Flight Attendant Uniforms

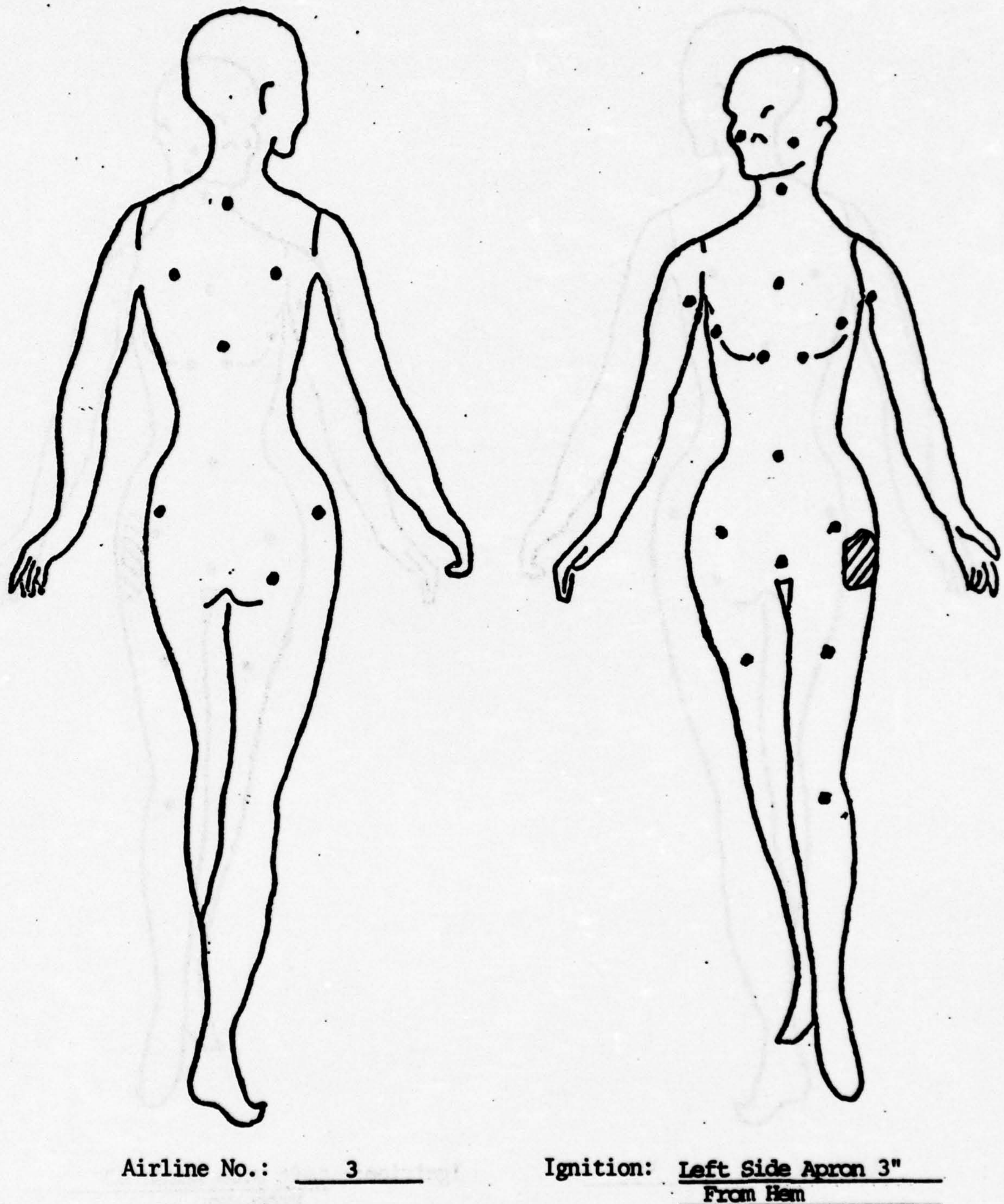


Airline No.: 3 Ignition: Left Side Apron 3" From Hem

Outfit: 65/35 Wool-Polyester Jumper
100% Polyester Bodysuit 50/50 Polyester/Cotton Apron

Time: 15 seconds Burn I.D. No.: 8-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

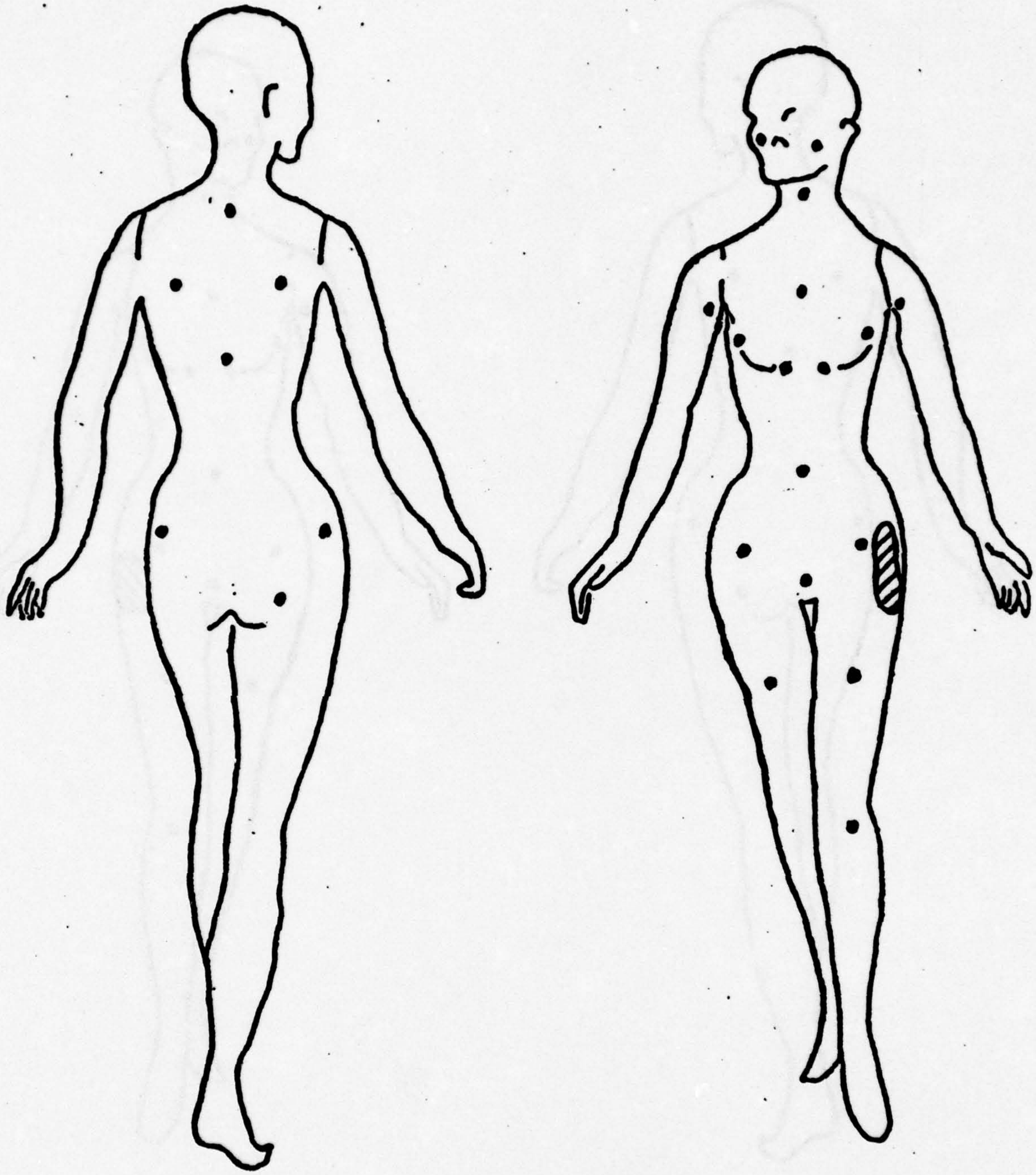


Airline No.: 3 Ignition: Left Side Apron 3" From Hem

Outfit: 65/35 Wool-Polyester Jumper
100% Polyester Bodysuit 50/50 Polyester/Cotton Apron

Time: 30 seconds Burn I.D. No.: 8-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 3

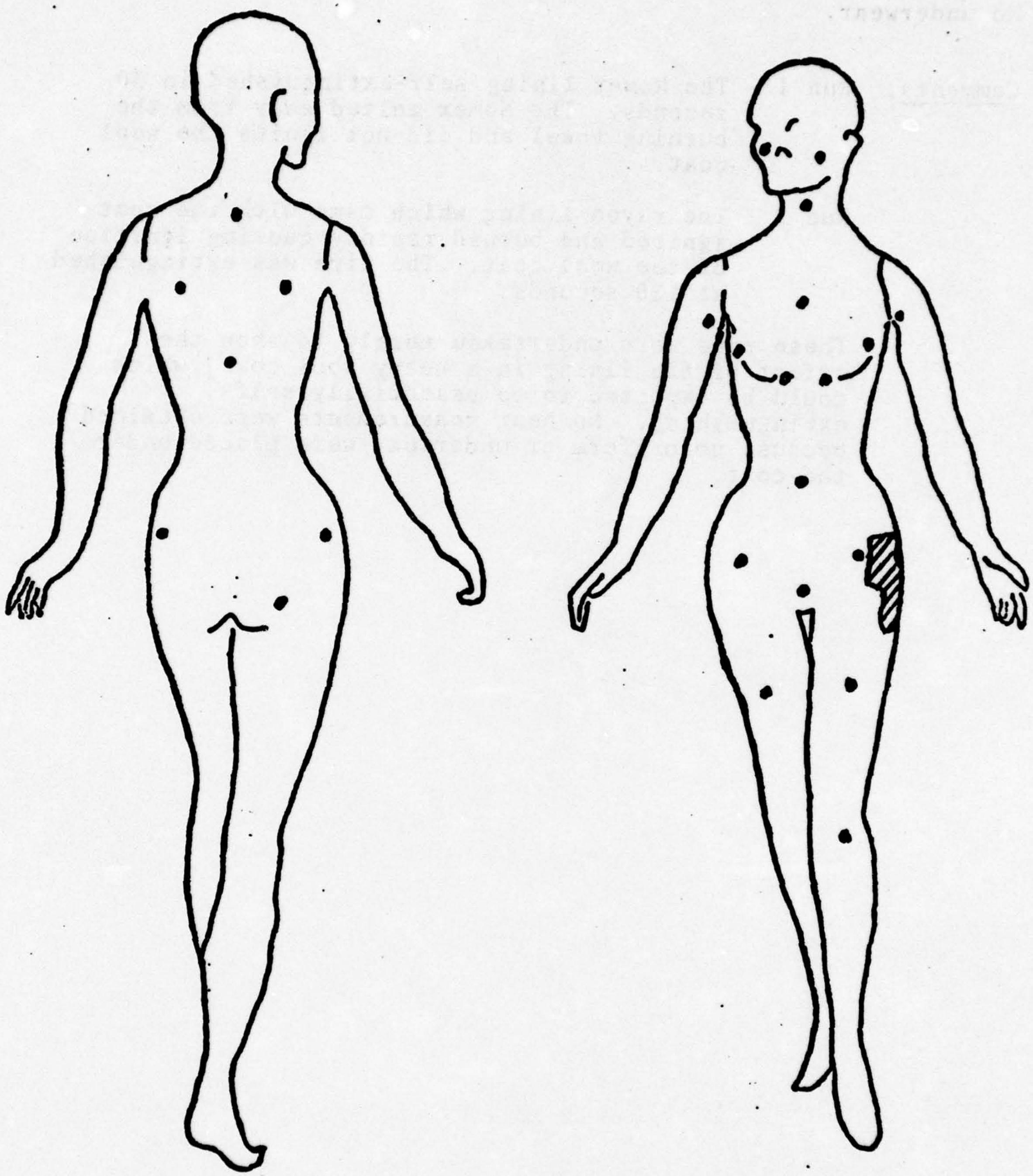
Ignition: Left Side Apron 3" From Hem

Outfit: 65/35 Wool-Polyester Jumper
100% Polyester Bodysuit 50/50 Polyester/Cotton Apron

Time: 45 seconds

Burn I.D. No.: 8-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 3

Ignition: Left Side Apron 3" From Jumper

Outfit: 65/35 Wool-Polyester Jumper
100% Polyester Bodysuit 50/50 Polyester/Cotton Apron

Time: 60 seconds

Burn I.D. No.: 8-1

BURN #9 - 1, 2

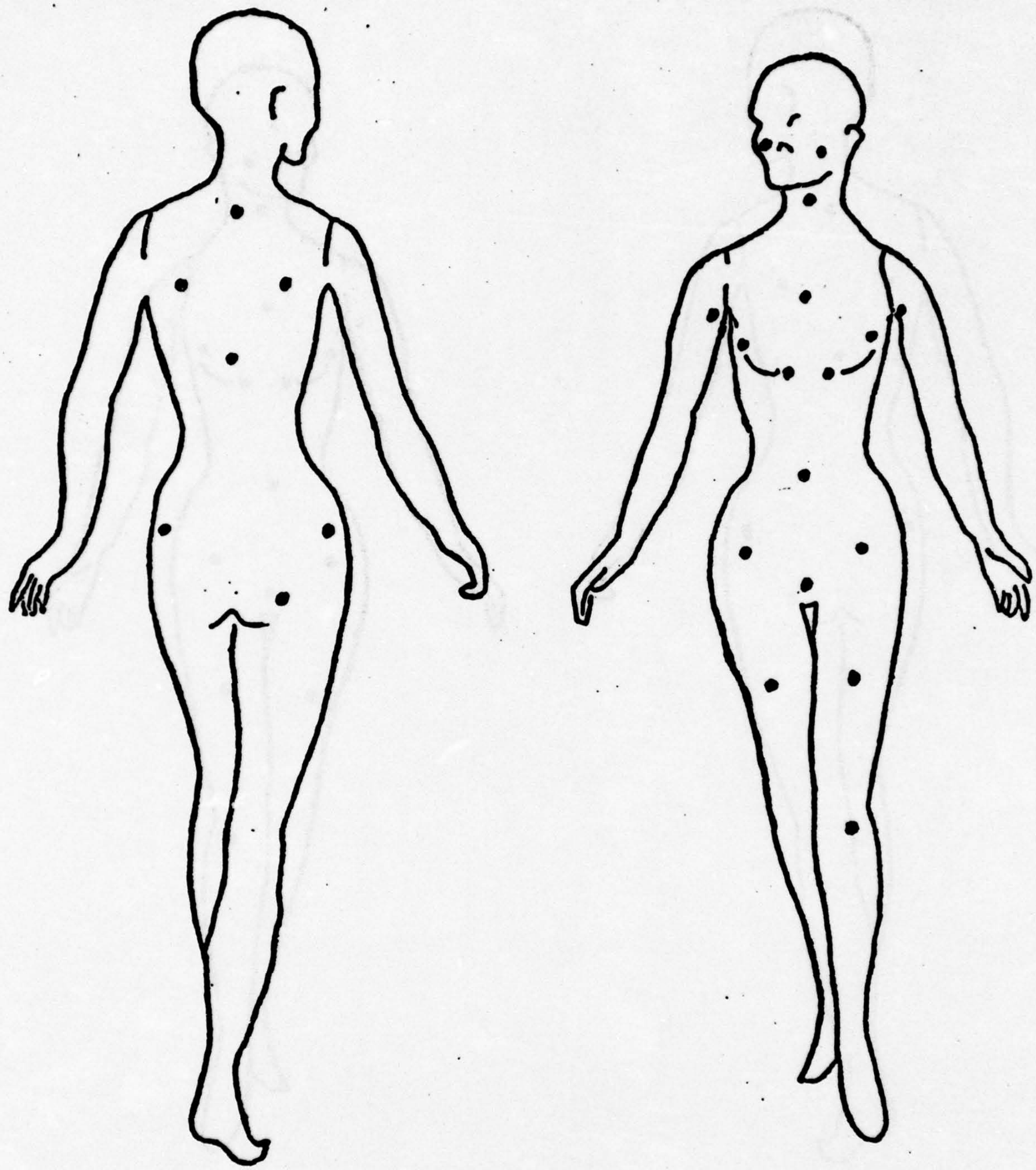
No underwear.

Comments: Run 1 - The Nomex lining self-extinguished in 30 seconds. The Nomex melted away from the burning towel and did not ignite the wool coat.

Run 2 - The rayon lining which came with the coat ignited and burned rapidly causing ignition of the wool coat. The fire was extinguished at 120 seconds.

These runs were undertaken merely to show the effect of the lining in a heavy wool coat, which could be expected to be essentially self-extinguishing. No heat measurements were obtained because no uniform or underwear were placed under the coat.

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

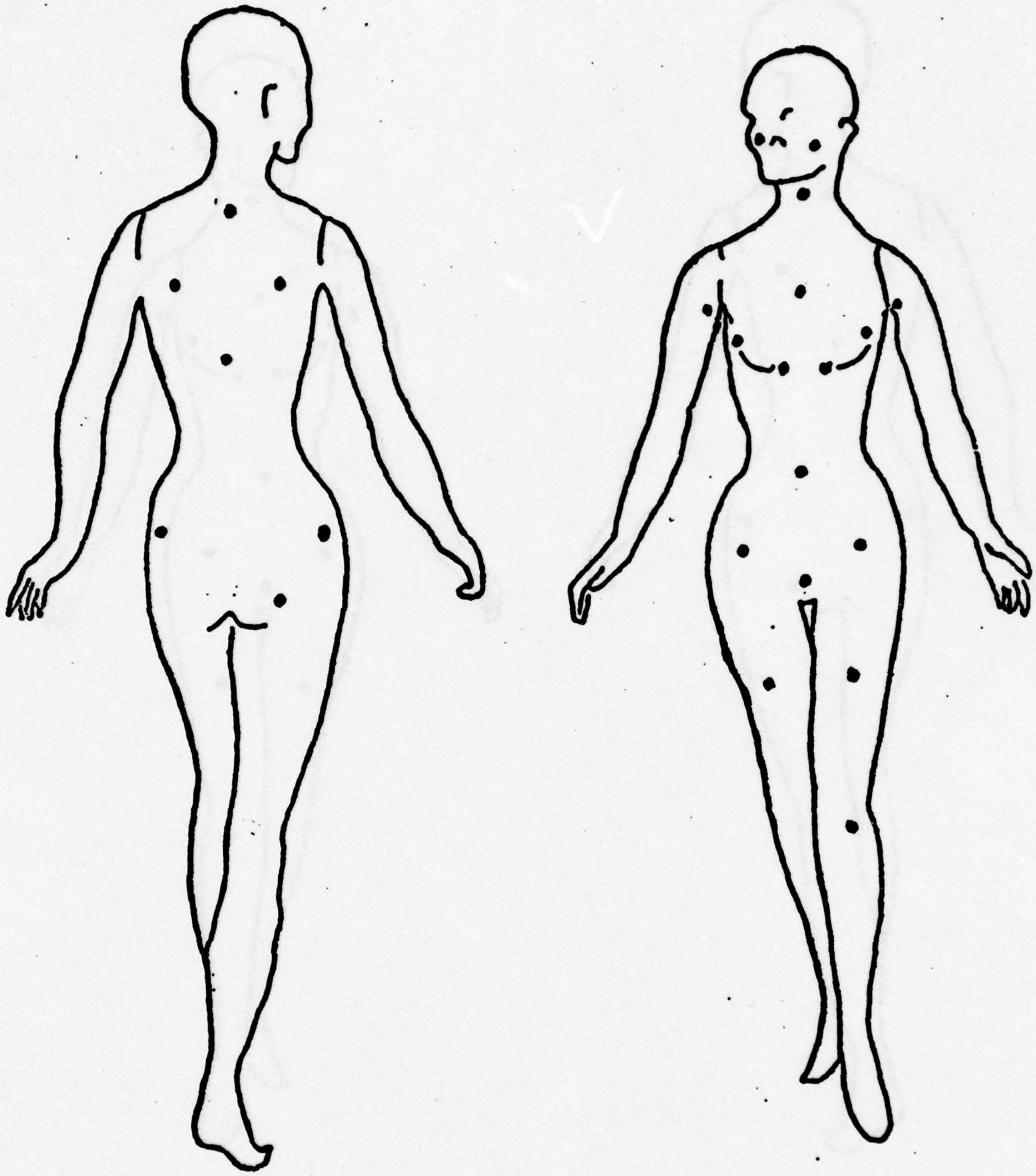
Ignition: Right Inside Coat Lining

Outfit: 100% Wool Topcoat
100% Nomex Lining

Time: 15 seconds

Burn I.D. No.: 9-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

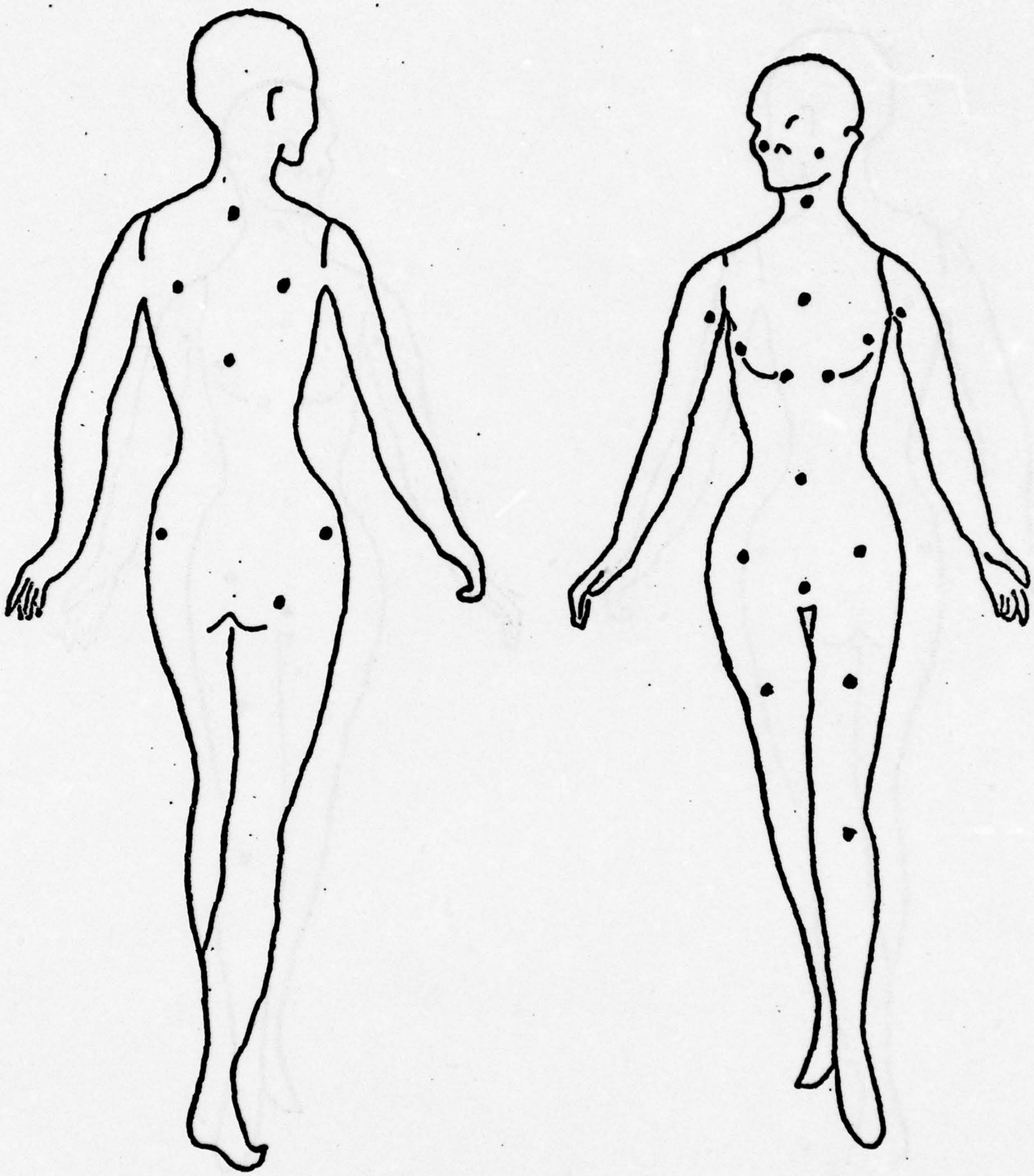
Ignition: Right Inside Coat Lining

Outfit: 100% Wool Topcoat
100% Nomex Lining

Time: 30 seconds

Burn I.D. No.: 9-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms

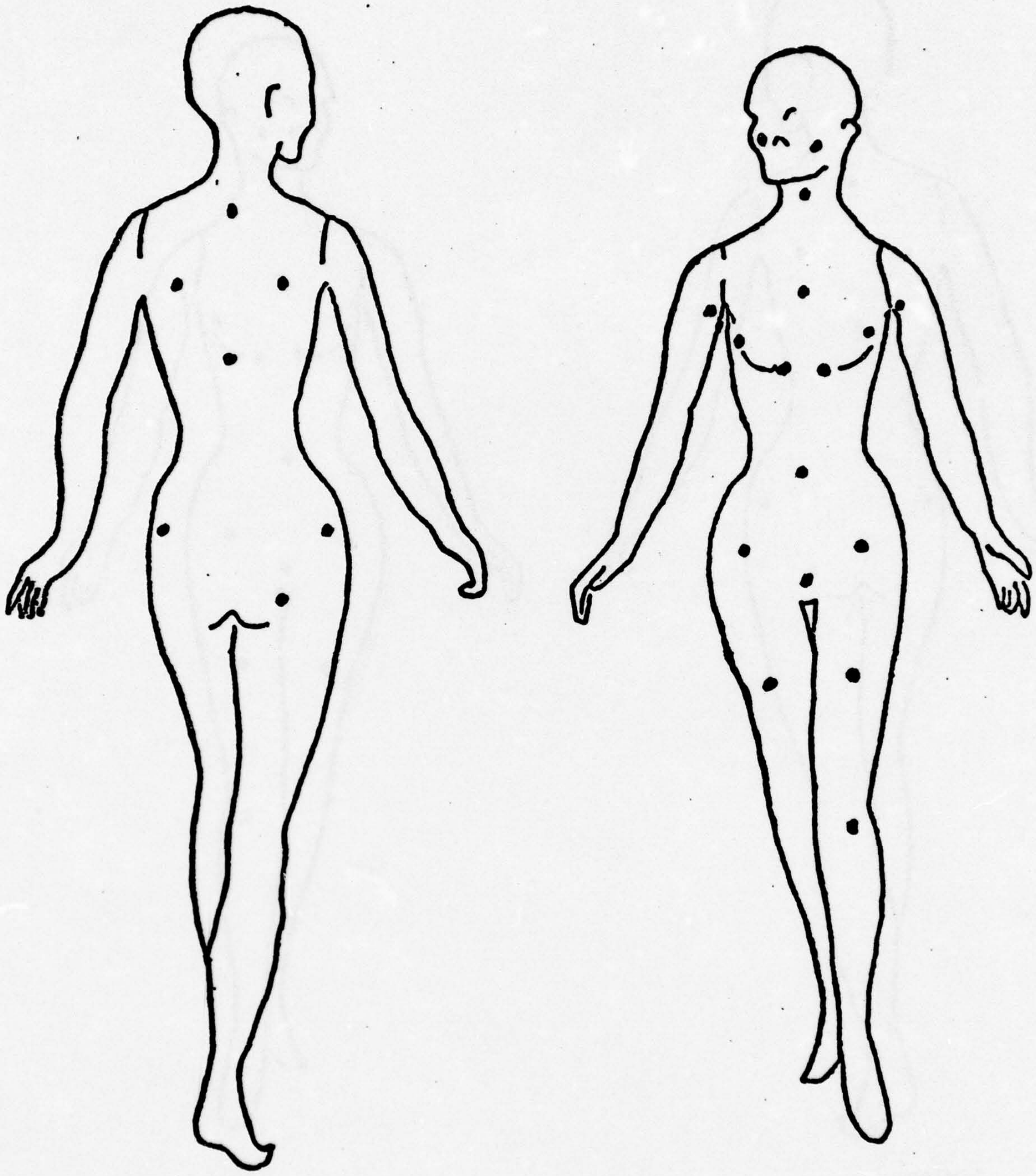


Airline No.: 1   Ignition: Right Inside Coat Lining

Outfit: 100% Wool Topcoat
100% Nomex Lining

Time: 45 seconds   Burn I.D. No.: 9-1

Heat Input to Mannequin From Burning Flight Attendant Uniforms



Airline No.: 1

Ignition: Right Inside Coat Lining

Outfit: 100% Wool Topcoat
100% Nomex Lining

Time: 60 seconds

Burn I.D. No.: 9-1

BURN #10

This uniform assembly (see p. A-95) was burned at Gillette Research Institute with the lining in the coat and at NBS without the lining.

Comments: Run 1 - Although Gillette registered no heat input to the mannequin, a human would presumably have been injured by breathing the hot gases and flames enveloping the face of the mannequin. The heavy alpaca lining of the raincoat was sufficiently thick and heavy that it retarded flame spread in the more flammable polyester/cotton raincoat. (Ref. P. A-92)

Run 2 - This run was done at NBS using the back of the raincoat from Run 1 except without the alpaca lining. In this test, the raincoat was worn over a polyester jumper and blouse, a nylon bra, nylon panties and panty hose, and with a vinyon wig.

Heat from the burning raincoat caused melt drip of the polyester onto the hose below. No heat measurements were obtained in this run; consequently, no heat input drawings are shown.

NOTE: See Section II of this Appendix for Burn #s 1, 10, 11 and 12.

BURN #13

<u>Uniform</u>: Skirt - 100% polyester

Shorts - 100% polyester

Blouse - 100% polyester

Smock - 100% polyester

<u>Underwear</u>: Bra - bust section, 100% nylon
elastic sections, 78/22 nylon/spandex

Panties - 100% nylon

Panty Hose - panty, 80/20 nylon/spandex
stockings, 100% nylon

<u>Wig</u>: 100% vinyon

<u>Comments</u>: The zipper in the center front of the smock helped to keep the fire going. The polyester fabric also burned. Flames reached the face. At the ignition site, the burn went through seven layers of uniform and underwear to the skin. There was some melt drip. In spite of this, no heat input exceeding 2 cal/cm^2 was recorded by the sensors.

BURN #14

Uniform: Jumper - 100% polyester

Blouse - 100% polyester

Underwear: Bra - bust, 100% nylon
elastic, 78/22 nylon/spandex

Panties - 100% nylon

Panty Hose - 100% nylon

Wig: 100% vinyon

Comments: Run 1 - The burning towel fell off at 50 seconds, but the jumper continued to burn tenuously to 70 seconds when it self-extinguished. There was some melt drip.

Run 2 - The burning towel fell off at 39 seconds, but the uniform continued to burn tenuously to about 60 seconds. There was some melt drip. Also, there was some heat shrinkage of the wig. No heat input exceeding 2 cal/ cm^2 was measured by the sensors.

APPENDIX A

Section II. Mannequin Burns of Presently Used Uniforms Conducted by Gillette Research Institute, Rockville, Maryland, for the National Bureau of Standards, Reference Report GRI Project 02-8218

"Burning Characteristics of Flight Attendant Uniforms on Mannequins Exposed to a Small Ignition Source"

by

Nancy Custer and Norman R. S. Hollies

March 31, 1975

[ABRIDGED]

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SUMMARY

[ABRIDGED]

The ignition and burning characteristics of four typical, currently used flight attendant uniforms have been examined on a size 10 female mannequin instrumented to sense heat transfer values at potential injury levels. Ignition and, where possible, burn behavior were documented.

Three female uniforms and one male uniform were examined using paper tab (small source) ignitions and, in two cases, gas torch ignitions. In instances where the initial ignition did not lead to a large fire, other ignition sites were tried.

All of the uniforms were found to ignite and two, a muumuu dress and a skirt/jacket combination, were found to impart sufficient heat to the mannequin to be equivalent to a moderately severe burn injury.

Tight-fitting clothing elements, or elements well separated from the fire by other layers, tended to burn least. Loose-fitting clothing with good access to air burned readily, and clothing fires between layers tended to be most intense. Flame spread by melt-drip was clearly evident in some fires, and highly flammable layers, held in place by the clothing restraints, often kept the fire going. No repeats were tried.

APPENDIX A - SECTION II

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LIST OF TABLES

LIST OF FIGURES

1. MANNEQUIN BURN METHODS (GRI)

Figure A1 shows the size 10 female mannequin in an A-line dress and a paper tab attached at the hemline ready for match ignition. The mannequin stands in a walk-in hood next to an aluminum mirror to aid in viewing garments at the back of the mannequin. The hood is used with positive ventilation during testing which gives a very low air flow around the mannequin surface of approximately 5 mph. Attached to the mannequin by an umbilical cord through the foot, is a recording system for reviewing the output of the 20 sensors located in the mannequin surface. The recording system and a large wall clock are activated simultaneously by a foot switch as actual ignition of the garment occurs. Fires are quenched either by putting them out with an asbestos glove or by use of a small CO_2 extinguisher.

Figure A2 shows the location of the heat flux sensors in the front and rear views of the mannequin. The 2.0 cm diameter copper discs which form the main sensing elements are painted black to act as suitable black body heat absorbers. Thermocouples in the sensors detect rate of temperature rise and have an average sensitivity of 5.2 cal/cm^2 per millivolt. Each location is sensed once per second and four locations are sensed at a time.

Paper tab ignition near the knee and at the chest was used in most cases in the present work, although on the first clothing ensemble ignition at the sleeve and collar, as well as torch ignition on the back (to simulate a short-time high energy ignition source), was also employed. In nearly every case, clothing fires were put out in 90 seconds to simulate the regulatory demonstration time requirement for cabin emergency evacuation.

2. DESCRIPTION OF CLOTHING SYSTEMS EXAMINED

A detailed listing of the components of each clothing system is given in Table A1. This listing is based on information supplied by the National Bureau of Standards at the time of each mannequin burn. Wigs, panty hose or socks, and shoes were included in each case even though, as seen in Figure A2, no heat sensors were available in these body areas to detect potential burn injury. The title listings of the garments in Table A1 will be used to describe these clothing systems in the remainder of the report.

3. RESPONSE OF CLOTHING SYSTEMS TO VARIATION IN IGNITION

Visual observations of the burn tests of each flight attendant clothing system at every ignition stage were used to document clothing behavior in time sequence. Heat transfer response data have been included as available to illustrate specific points about each clothing system's response to flame. As mentioned earlier, these analyses describe what happened to a particular clothing sample, but cannot, by themselves, be extended to represent what would happen in repeat fires on the same clothing systems.

3.1 System 341-2-Female, Light Brown, Double Knit Suit (NBS Burn #1)

Ignition of this particular clothing system was done at eight locations and, where burning occurred, the flame was extinguished at 90 seconds. Heat pulse information detected by the mannequin sensors in these burns was not sufficiently detailed to give reliable heat flux values. This behavior is characteristic of short burns of less than 10 seconds and in small-scale fires where the actual burning clothing elements do not approach any particular sensor at the mannequin surface. The descriptions below, therefore, are based on analyses of the data and are given in chronological order by ignition location.

3.1.1 Skirt Hemline Ignition

Burning occurred mainly by melt-drip, dripping commencing by 12 seconds and producing an inverted V-pattern in the front of the skirt. The ignition tab fell off a 22 seconds, but the edge of the jacket ignited from the skirt. The melted jacket became fused to the skirt layers underneath.

3.1.2 Sleeve Hem Ignition

Burning of the sleeve commenced in a melt-drip fashion, the ignition tab falling off at 18 seconds. Drips of 2 to 3 seconds continued to burn on the floor of the hood. Approximately 6 inches of the sleeve had been burned when the fire was extinguished at 90 seconds.

3.1.3 Mid-Chest Ignition

The area around the ignition tab burned until, at 12 seconds, the tab and part of the burning blouse fell down onto the skirt, setting it on fire. Melt-drip burning continued until it was smothered by glove at 90 seconds.

3.1.4 Right Lapel and Chest Ignition

There was a faster flame spread from this ignition, mainly up the inside of the jacket. Flames burst through the backside of the lapel facing at 30 seconds to burn the scarf, and reached the head, scorching the right side of the wig. There was melt-drip from the lapel which reignited the skirt. A portion of the lapel and the ignition tab fell off at 48 seconds, igniting more of the skirt. At the same time, fire spread across the blouse at the neckline, with melt-drip igniting the scarf and the left lapel, the fire spreading downward. After extinguishing the flame at 90 seconds, much of the front of the blouse had burned away but leaving most of the bra intact.

3.1.5 Low-Back Jacket Ignition

Initial melt-drip burning occurred on the jacket extending to the skirt. The glow of the fire was visible inside the skirt and, at 70 seconds, fire burst through the skirt on the left side. By the time the fire was doused with CO_2 at 90 seconds, most of the back of the skirt had been consumed by fire. The double thickness of fabric at the hemline, however, did not fall away.

3.1.6 Torch Ignition Below Back of Left Shoulder

A home repair type propane torch was applied at a 30° angle to the jacket cloth for 3 seconds. A hole was burned where the flame touched, and the fire continued to 13 seconds before self-extinguishing.

3.1.7 Torch Ignition Below Back of Right Shoulder

A 3-second ignition was used with the torch aimed from above. The flame went out on removal of the torch. Where the fabric was loose on the left shoulder, more burning occurred beyond the initial ignition point.

3.1.8 Tab Ignition, Center-Back of Collar

The ignited collar scorched the wig. The wig became charred and considerable smoke was produced. As the ignition tab did not fall off, fire spread around the collar, aided by the scarf, and down the back of the jacket. Surprisingly, melt-drip from this area did not ignite the back of the jacket. The fire was extinguished with CO_2 at 90 seconds.

3.1.9 Summary

The general characteristics of burning of this uniform were predominantly melt-drip, and where these fell on the mannequin (left leg, for example), the molten polymer clung to the mannequin surface and had to be scraped off. Flame spread when melt-drip occurred was generally slow, except for the instances under the jacket (front) and under the skirt (rear) where a lot of air was available, in which case flame spread was very rapid, covering much of the mannequin. Reignition of lower garment areas from melt-drip of clothing above the waist was repeatedly seen.

3.2 System 341-4 - Female, Polyester Muumuu (NBS Burn #11)

3.2.1 Ignition at Knee

The area around the ignition tab burned slowly and steadily before and after the tab fell off at 25 seconds. Main flame progression was downward which finally self-extinguished at 67 seconds.

3.2.2 Ignition at the Chest

Melt-drip from the chest fell onto and ignited the abdomen section. The ignition tab fell off at 11 seconds. By 25 seconds, there were two areas burning, one at midchest and one at the pelvis, with continuing melt-drip onto the waist area. By 40 seconds, the midriff area of the dress was burned away, including the nylon bra cups. At 60 seconds, the lower pelvis area ceased to burn, but burning at the waist and chest continued. The fire was extinguished at 90 seconds, revealing some holes in the panty hose but little damage to the panties. The front of the dress was sufficiently burned out so the dress fell open down to the midthighs. The chest area was burned out except for the neck facing with double fabric thickness.

Heat Sensor Response - Systems 341-2, 341-4

Heat received by the mannequin sensors was substantial. Sensors #7, #8, and #9 picked up heat pulses, as summarized in Figure A3. Sensor #8, in the low abdomen region, received the first strong heat pulse, beginning about 10 seconds and lasting to 40 seconds after ignition and corresponding to the first melt-drip from the chest. Beginning at 50 seconds, the continuing melt-drip and burning in these regions produced a second, slightly stronger, heat pulse sensed by the mannequin, which peaked at 70 seconds but continued until the fire was put out. The "injury line" drawn in Figure A4 is taken from the skin burn work of Stoll and Chianta [Aerospace Med. 40 1232 (1969)] which establishes that a second-degree burn is possible on human skin if the heat received is greater than 2 cal/cm^2 and the heat flux exceeds .05 cal/cm^2-sec. For comparison purposes, all the heat transfer values in Figure A4 occurred at heat flux values greater than .05 cal/cm^2-sec and, for sensor #8, these exceeded 0.4 cal/cm^2-sec at 65 seconds from ignition and beyond. Either heat pulse of the intensity detected by sensor #8 would cause permanent injury on human skin.

Nearby, sensor #7 also detected heat pulses at approximately 30 seconds and beyond 60 seconds, presumably from the same melt-drip and cloth burning at the waist. By the same criteria, the first of these pulses would be painful, the second injurious. As the sensor #9 data in Figure A4 shows, fire reached the right thigh from the burning dress at about 30 seconds and became quite severe in this area at 50 seconds, and ceased to burn after 60 seconds. The heat pulse, however, at 50 seconds was quite adequate for permanent injury to this part of the leg.

This information on heat transfer to the mannequin certainly provides, in this instance, a means of estimating how serious injury might be from dress fire with only moderate rate of flame spread, but producing melt-drip onto parts of the body and direct transfer of heat to these skin areas. In spite of the fact that the heat sensors cannot, because of their fixed location, be expected to pinpoint local burn intensities, they can and do, as in this instance, provide a useful means for assessing real injury over a modest skin area. Furthermore, they provide a direct means for assessing whether the burning clothing fabric actually makes skin contact and this determination is often not possible with visual methods of fire assessment.

3.3 System 341-5 - Male Suit Plus Raincoat NBS Burn #10)

3.3.1 Coat Ignition at Knee

Ignition at the left bottom edge of the raincoat produced a flame front upwards inside the coat, and smoke appeared at the right trouser leg and sleeve. External flames appeared at about 25 seconds, and by 35 seconds, were traveling up the coat front. By 60 seconds, flames on the coat had extended to the waist, and smoke continued to pour out the left and back areas. In 100 seconds, flames had reached the necktie, and by 120 seconds, when the fire was extinguished, they had reached the wig. The coat liner and zipper tape continued to smolder and had to be patted out with the asbestos glove.

The suit ensemble was damaged only in a few areas: about the collar and the left trouser pant leg. The alpaca wool lining was fairly intact. No special heat pulses were received by any of the mannequin sensors. Hence, in spite of considerable burning of the clothing system outer-layers, there was little damage at the skin level and no evidence of melt-drip occurring. The raincoat and zip lining face appeared to be the most flammable components. (Also refer to Burn No. 10, Section I, Appendix A.)

3.4 System 341-6 - Female Red Suit (NBS Burn #12)

3.4.1 Skirt Ignition at Knee

The area around the ignition tab burned for 30 seconds and the fabric smoldered until extinguished at 100 seconds with asbestos glove.

3.4.2 Skirt Ignition at Jacket Hem Level

Ignition tab was placed on skirt below the left hip, 30 inches from the floor. Initial burning occurred under jacket mainly on the left side; flames were visible at jacket hemline in mirror behind mannequin. At 30 seconds, the ignition tab fell to the floor, and melt-drip continued from this area. By 55 seconds, smoke was seen coming outside the jacket on the left side from waist to chin. Even by 90 seconds, open flames were seen mainly in the mirror, although a glow developed inside the left side of the jacket. At 115 seconds, flames burst through the jacket and up the outside, concentrating under the left arm. CO_2 was used to stop the fire at 135 seconds.

Close examination of the clothing revealed that the thigh portion of the panty hose had been melted away, as well as part of the pants portion of the body suit. There was a large hole in the body suit under the left underarm and some scorching of the bra on this side. Below this, the skirt was burned away between the waistband and midthigh. The left side of the jacket was burned away from lower hem to the underarm, and the polyester lining was severely melted.

Fire progression and ultimate damage were readily reflected in heat transfer to the mannequin. Comparing Figure A2 with Figure A4, we see that sensor #20 on the left thigh detected a heat buildup at 20 seconds, reaching a damaging peak of 4 cal/cm^2 at 38 seconds. The progressive fire in this region continued to receive heat from burning skirt materials and reached another peak of 9.2 cal/cm^2 in 90 seconds. By 118 seconds, the heat flux was off scale. Heat buildup under the arm at sensor #4 was first noticed at about 30 seconds and continued above the line for skin injuries throughout the remainder of the fire. Sensor #16, at the lower left waistline, detected heat first at 60 seconds, building to the injury line at 92 seconds, and proceeding off scale at 130 seconds. Thus, although the fire was slower to develop than many of the others, the heat transfer to the mannequin was ultimately much higher and, therefore, potentially more dangerous. As with other examples, heat trapped under the jacket gave rise to an intense fire of high hazard value.

TABLE A1

DESCRIPTION OF CLOTHING SYSTEMS USED IN FLAME TESTS ON MANNEQUINS

341-2 Female, Light Brown, Double Knit Suit (NBS Burn #1)

1. White bra -- bust sections of 100% Antron nylon; elastic sections 78% nylon/22% spandex
2. White bikini panties -- 100% nylon tricot
3. White mini slip -- 100% nylon
4. Panty hose -- 80% stretchable nylon + 20% spandex
5. Blue blouse -- 100% nylon knit
6. Light brown A-line skirt -- 100% polyester double knit
7. Light brown blazer -- 100% polyester double knit fully lined with 100% polyester
8. White, brown, blue, and red neck scarf -- 100% polyester
9. Blonde wig -- 100% modacrylic
10. Camel color shoes -- man-made material, wet look vinyl

341-4 Female, Polyester Muumuu (NBS Burn #11)

1. Bra -- 100% nylon cup with elastic of nylon spandex
2. Panties -- 100% nylon
3. Panty hose -- 100% nylon + 80% nylon + 20% spandex
4. Muumuu -- 100% polyester
5. Wig -- 100% modacrylic
6. Shoes -- man-made material

TABLE A1 (Con't)

341-5 Male, Suit Plus Raincoat (NBS Burn #10)

1. T-shirt -- 75% cotton/25% polyester
2. Briefs -- 75% cotton/25% polyester
3. Shirt -- 65% polyester/35% combed cotton
4. Necktie -- fabric not known
5. Trousers -- 55% polyester/45% wool
6. Suit coat -- 55% polyester/45% wool, partial lining of rayon, hair canvas interfacings, shoulder pad (possibly cotton backing)
7. Raincoat -- outer-fabric, 65% polyester/35% cotton; zip lining face, 100% pure alpaca back, 51% rayon/49% cotton sleeve; 100% nylon woven interfacing in front facings
8. Wig -- human hair
9. Socks -- tops, 73% acrylic/25% nylon/2% spandex; feet, 63% acrylic/37% nylon
10. Shoes -- leather

341-6 Female, Suit (NBS Burn #12)

1. Bra -- 100% nylon cup with elastic of nylon spandex
2. Panties -- 100% cotton
3. Panty hose -- 100% nylon
4. Body suit -- 100% polyester with bikini portion, woven interfacing in facings and collar
5. Skirt -- 65% wool/35% polyester lined with polyester, woven interfacing in right front skirt opening, pockets, and waistband

TABLE A1 (Con't)

6. Jacket -- 65% wool/35% polyester lined with 100% polyester, woven interfacings around neck and down front openings

7. Wig -- 100% modacrylic

8. Shoes -- man-made material

FIGURE A1: MANNEQUIN BURN EQUIPMENT, FEMALE SIZE 10

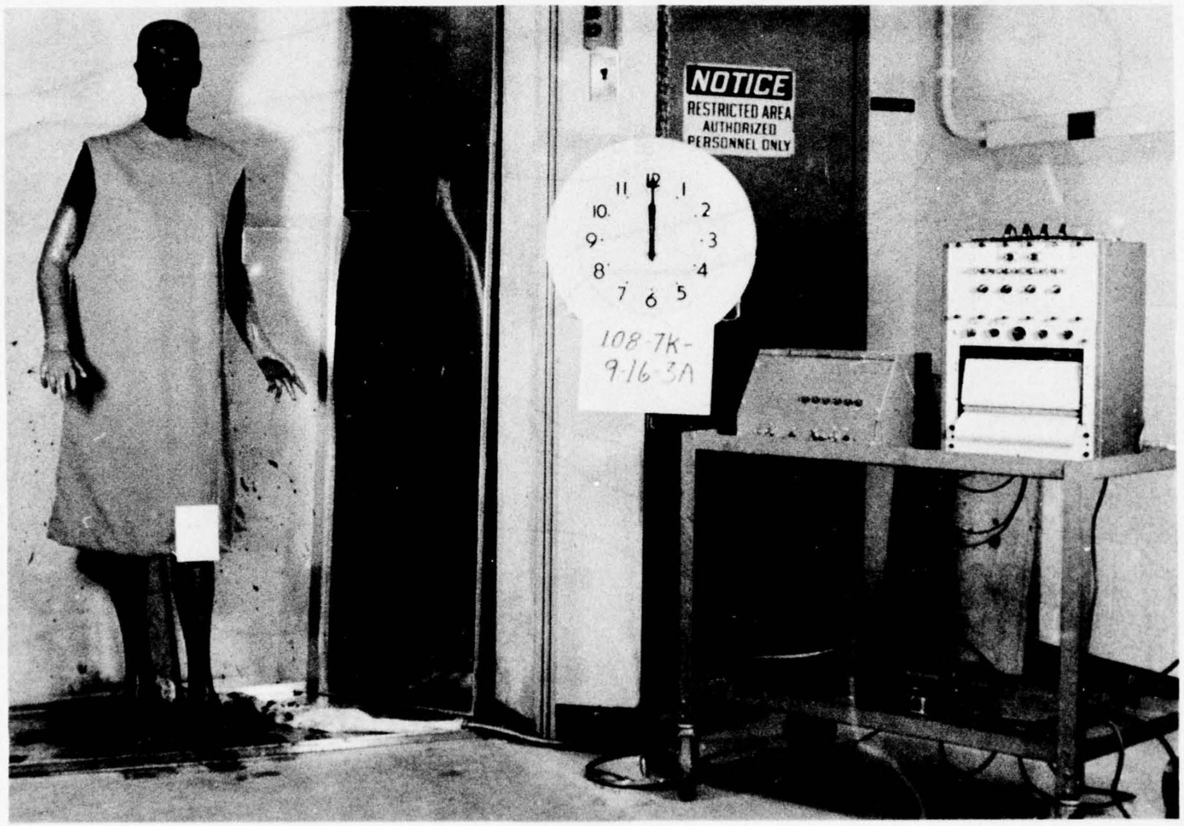


FIGURE A2: LOCATION OF SENSORS IN FEMALE, SIZE 10 MANNEQUIN (GRI)

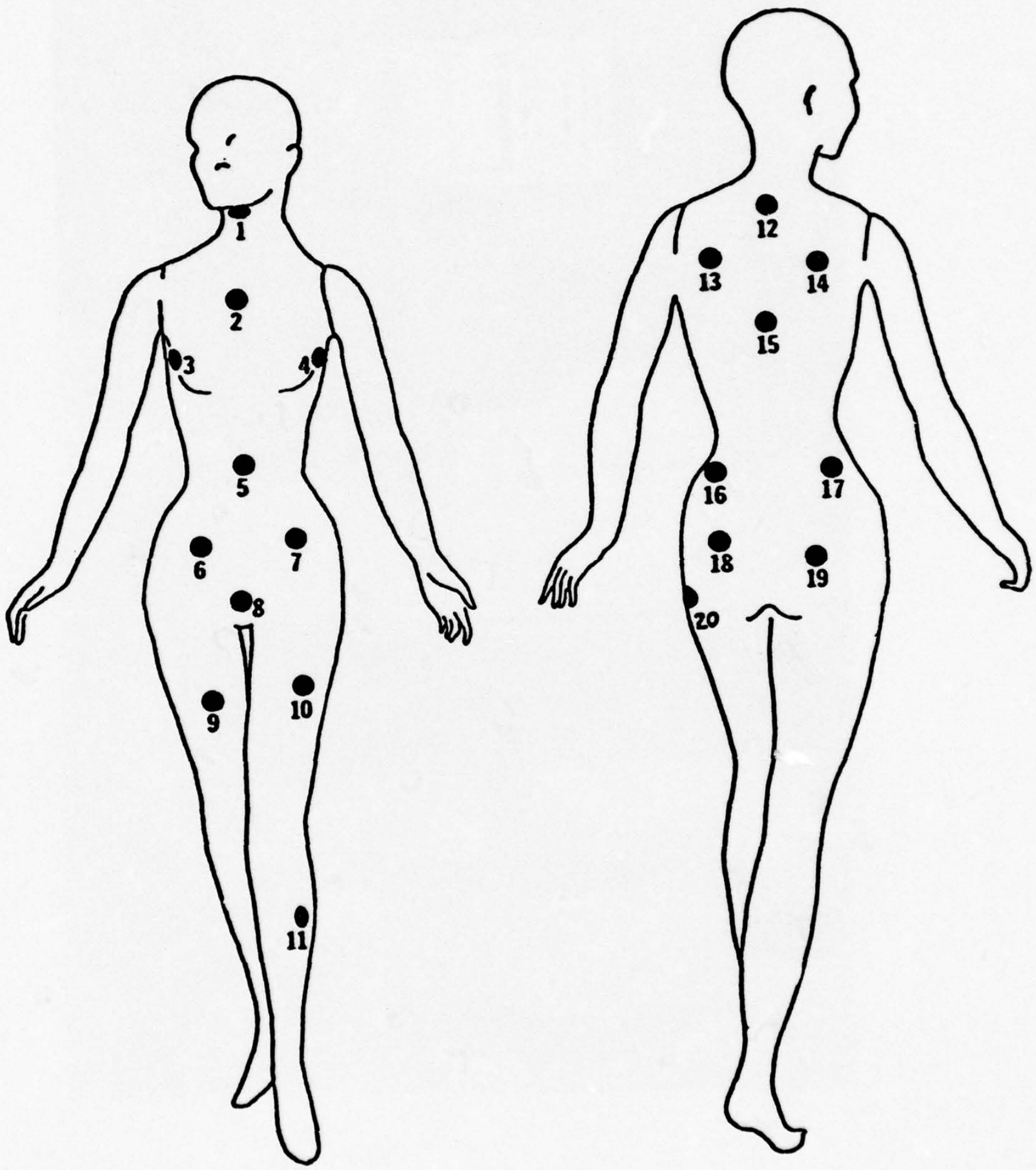


FIGURE A3

HEAT SENSOR RESPONSE TO MANNEQUIN BURN 341-4-2

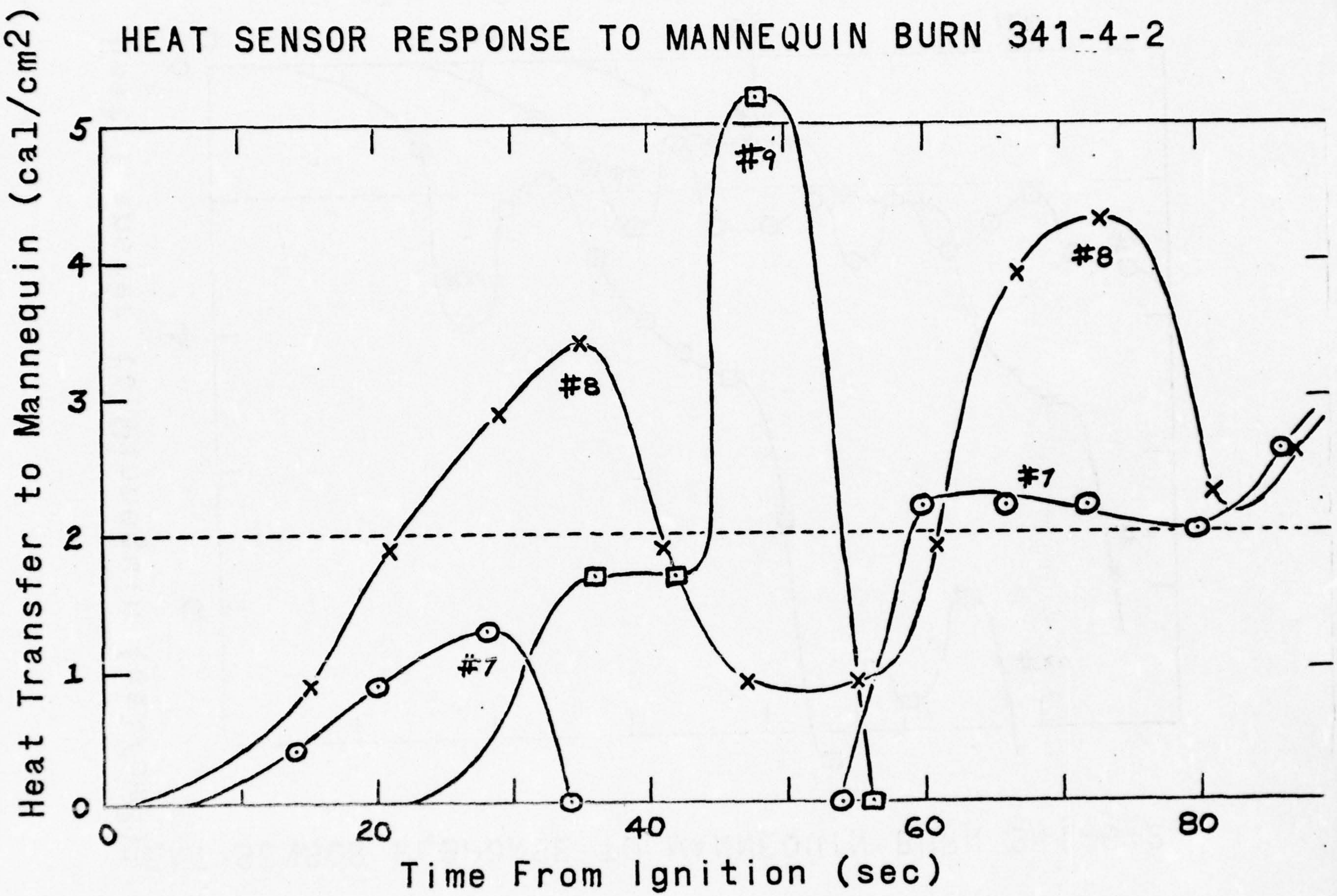
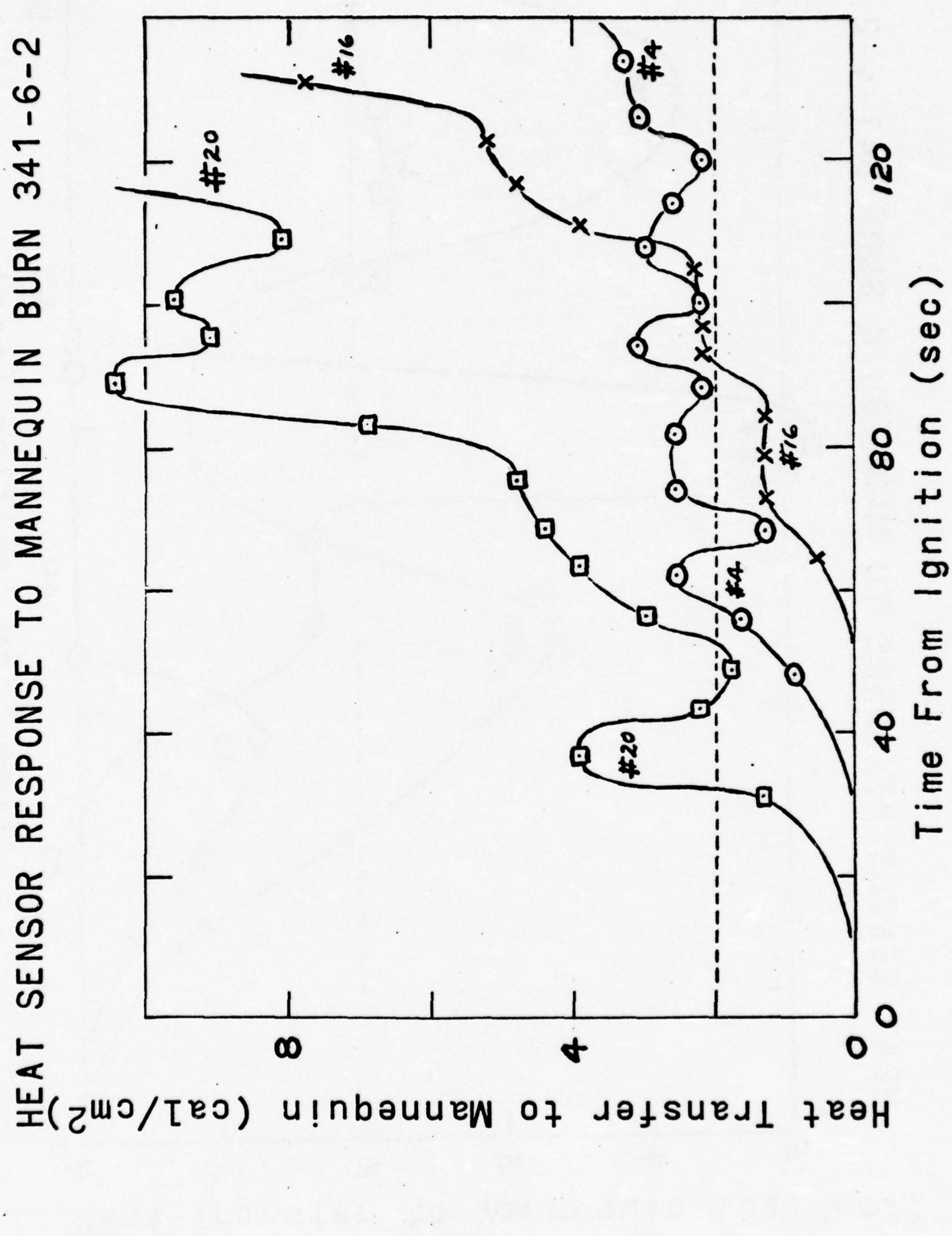


FIGURE A4



HEAT SENSOR RESPONSE TO MANNEQUIN BURN 341-6-2
Heat Transfer to Mannequin (cal/cm²)
Time From Ignition (sec)
0
4
8
0
40
80
120
#20
#20
#4
#4
#16
#16

APPENDIX B

Mannequin Burns of Prototype Uniforms Made From FR Fabrics

Introduction

The objective of these mannequin burn tests was to demonstrate the behavior of prototype garments made from FR fabrics. This appendix should be read in conjunction with the other data given in this report. The fabrics used are described on page 41, paragraph 2.5 of the report. They were chosen because they passed the FF 5-74 tests, and because they were otherwise reasonably similar to the fabrics presently used in F/A uniforms in apppearance and feel. The FR treated polyester fabrics chosen for the mannequin burns would not pass the proposed standard because of melt hole formation and because of low heat flux resistance. However, they were of technical interest because they pass FF 5-74, and because they are widely used in applications where only self-extinguishment is required.

No significant heat transfer to the mannequins was recorded during most of the burns, except in the area of the ignition source. Consequently, no figures showing potentially burned skin areas are attached. However, the FR polyester blouses used in burns 15-2, 15-3, 17-2, 18-2, and 23-4 formed holes in the area of the ignition source, and the underlying bras caught fire. This did not occur when a Nomex blouse of similar weight was used.

Burn #9 is a wool coat presently used by one of the major airlines. However, when delivered to us, it had a rayon lining, which burned readily (Burn #9-2, Appendix A). We fitted the remainder of the coat with a Nomex lining, and it did not ignite.

As in the case of the burns described in Appendix A, some of the burns were conducted at Gillette Research Institute and others at NBS. The Gillette Research Institute report is included in Section II of this Appendix. The Gillette Research Institute observed heat sensor responses during the above mentioned burns and attached the time-heat curve to their report. It is, again, emphasized that the heat response was from the ignition source or the bra, not the burning fabrics of the prototype uniforms.

The burns are listed and described in the following pages.

APPENDIX B

Section I. General Description of All Burns

BURN #15

Gillette Research Institute Report, July 3, 1975, Burn #15. (P. B11)

Runs 1 and 2

Uniform: Jacket - 100% wool, FR, double knit, 11.3 oz/sq yd

Pants - 100% wool, FR, double knit, 11.3 oz/sq yd

Body Suit - 100% polyester, FR, 3.5 oz/sq yd

Underwear: Bra - cups, nylon
elastic, nylon/spandex
lightly padded cup, fiber unknown

Panties - 100% nylon

Knee-High Hose - 100% nylon

Shoes: leather

Wig: 100% vinyon

Run 1: Ignition site - bottom edge center front of jacket. No heat input indicated.

Run 2: Ignition site - center front of chest of blouse directly over bra.

Polyester blouse melted and bra burned.

Run 3

The clothing system was the same as Run 1, except the jacket was not used.

Ignition site - center back of blouse over bra back strap. The polyester blouse melted, and the bra back strap burned.

BURN #16

Gillette Research Institute Report, July 3, 1975, Burn #16. (P. B12)

Uniform: Pants and Tunic - 100% FR rayon, 4.5 oz/sq yd, with the pants lined with 100% Nomex, 1.6 oz/sq yd

Underwear: Bra - cups, nylon
elastic, nylon/spandex

Panties - 100% nylon

Knee-High Hose - 100% nylon

Shoes: leather

Wig: 100% vinyon

Ignition site - bottom edge center front of tunic. The tunic had a low V-neck. Smoke came up through the neck opening. Heat input was registered at sensor #2.

BURN #17

Gillette Research Institute Report, July 3, 1975, Burn #17. (P. B12)

Runs 1 and 2

Uniform: Muumuu - 100% polyester, FR, 3.5 oz/sq yd

Underwear: Bra - cups, nylon
elastic, nylon/spandex

Panties - 100% nylon

Panty Hose - 100% nylon

Shoes: leather

Wig: 100% vinyon

Run 1: Ignition site - center front at knee level. No heat input indicated.

Run 2: Ignition site - center front at waistline. Sensor #5 was under the ignition source. The bra ignited from the tenuously burning muumuu. The heat input at sensors #1 and #2 resulted from the burning bra.

BURN #18

Gillette Research Institute Report, July 3, 1975, Burn #18. (P. B12)

Runs 1 and 2

Uniform: Muumuu - 100% polyester, FR, 4.7 oz/sq yd

Underwear: Bra - bust, 100% nylon
elastic, 78/22 nylon/spandex

Panties - 100% nylon

Panty Hose - 100% nylon

Shoes: leather

Wig: 100% vinyon

Run 1: Ignition site - center front of skirt at knee level. No injury indicated.

Run 2: Ignition site - left side at waistline. The muumuu burned tenuously until about 45 seconds, when the bra ignited. Sensors #1 and #2 registered heat input from the burning bra.

BURN #19

Gillette Research Institute Report, July 3, 1975, Burn #19. (P. B12)

Run 1

Uniform: Blouse - 100% polyester, FR, 2.4 oz/sq yd

Skirt - 100% wool, FR, 8.7 oz/sq yd

Underwear: Bra - 100% nylon

Panties - 100% nylon

Panty Hose - 100% nylon

Shoes: leather

Wig: 100% vinyon

Ignition site - center front of skirt just above knee level. No heat input indicated.

Run 2

Same clothing system as Run 1, except the wool skirt was lined with Nomex, 1.6 oz/sq yd.

Ignition site - same as Run 1. No heat input indicated.

Run 3

Same clothing system as Run 1, except the skirt was a 65/35 FR rayon/polyester blend, 7.0 oz/sq yd.

Ignition site - same as Run 1. Heat input at sensor #9 was a result of the ignition source.

BURN #20

Gillette Research Institute Report, July 3, 1975, Burn #20. (P. B13)

Run 1

Uniform: Blouse - 100% Nomex, 3.9 oz/sq yd

Skirt - 75/25 wool/polyester, FR, double knit, 8.9 oz/sq yd

Underwear: Bra - 100% nylon

Panties - 100% nylon

Panty Hose - 100% nylon

Shoes: leather

Wig: 100% vinyon

Ignition site - center front of skirt just above knee level. No heat input indicated.

Run 2

Same clothing system as Run 1, except the skirt was an FR cotton fabric.

Ignition site - same as Run 1. No heat input indicated.

Run 3

Same clothing system as Run 1, except the skirt was 100% Nomex, 5.0 oz/sq yd.

Ignition site - same as Run 1. Heat input was a result of the ignition source.

BURN #21

Gillette Research Institute Report, July 3, 1975, Burn #21 (P.B13)

Run 1

Uniform: Blouse - FR rayon, 4.5 oz/sq yd

Skirt - Kynol/Nomex, 8.3 oz/sq yd

Underwear: Bra - nylon

Panties - nylon

Panty Hose - nylon

Shoes: leather

Wig: 100% vinyon

Ignition site - center front of skirt at knee level. No heat input indicated.

Run 2

Same clothing system as Run 1, except for the addition of a Nomex apron, 6.2 oz/sq yd.

Ignition site - center front bottom edge of apron. This Nomex apron was treated to be water and oil repellent which may have been contributing factors to its burning. The apron burned slowly only to the belt at the waist and self-extinguished by 60 seconds.

Runs 3 and 4

Same clothing system as Run 1, except the skirt was 100% FR polyester, 5.4 oz/sq yd.

Run 3: Ignition site - same as Run 1. No injury indicated.

Run 4: Ignition site - left side seam just below hip level. Heat input indicated was from ignition source.

BURN #22 (NBS TEST)

Runs 1 and 2

Uniform: Raincoat - 100% Nomex, water repellent, 5.2 oz/sq yd, lined with Nomex, 1.6 oz/sq yd

Skirt - 100% polyester, FR, 5.4 oz/sq yd

Blouse - 100% Nomex, 3.9 oz/sq yd

Underwear: Bra - cups, polyester
back and sides, 76/24 nylon/spandex
pad, polyurethane

Panties - 100% nylon

Panty Hose - panty, 80/20 nylon/spandex
stockings, 100% nylon

Wig: 100% vinyon

Run 1: Ignition site - front left thigh of raincoat. No heat input indicated.

Run 2: Ignition site - left back just above waistline. No heat input indicated.

BURN #23 (NBS Test)

Runs 1, 2, and 3

Uniform: Skirt - 100% polyester, FR, 6.8 oz/sq yd

Blouse - 100% Nomex, 3.9 oz/sq yd

Underwear: Bra - bust, 100% nylon
elastic, 78/22 nylon/spandex

Panties - 100% nylon

Panty Hose - panty, 80/20 nylon/spandex
stockings, nylon

Wig: 100% vinyon

Run 1: Ignition site - center front of skirt just above knee level. No heat input indicated.

Run 2: Ignition site - center back of blouse between shoulder blades. No heat input indicated.

Run 3: Ignition site - center front of blouse over bra. No heat input indicated.

Run 4

Same clothing system as Run 1, except the blouse was 100% FR polyester, 2.4 oz/sq yd.

Ignition site - center front of blouse over bra. Heat input was from the burning bra.

APPENDIX B

Section II: Mannequin Burn Tests of Uniforms Made From FR Fabrics (Gillette Research Institute Test Report, July 3, 1975, by Nancy Custer, ABRIDGED)

This report covers the data and observations on the mannequin burns of the flight attendant uniforms done at GRI on May 20, 1975.

The mannequin burn method was the same as described in Appendix A, Section II. The same size 10 female mannequin was used with a 4-channel recorder reading the input from each of the 20 sensors, once per second. Figure B1 shows the location of the heat flux sensors in the front and rear views of the mannequin. A large clock with a sweep second hand was activated by a foot pedal switch simultaneously with the recording system.

A paper tab lit with a match, as used in the earlier mannequin burn trials on F/A uniforms, was again used as the ignition source. The paper tab was first pinned to the garment at either the hem of the skirt or jacket, then at mid-chest. Where initial ignition did not lead to a large fire, other ignition points were tried, like the one at mid-back on Burn #15, Run 3. The recording system and clock were activated when it was determined that the garment itself was ignited. Following ignition, each test ran for 90 seconds at which time the fire was put out with a portable CO_2 extinguisher or padded out with an asbestos glove.

The burning behavior analyses which follow are based on heat flux data and corresponding observations.

All burn runs which were found to have a heat flux greater than .05 cal/cm^2-sec are represented in Figures B2-10. The dotted line on each of the graphs at 2 cal/cm^2 represents the "injury line" discussed in Appendix A, Section II. On each of these figures is listed a description of the main garment components for that burn run. In addition to those components listed, every garment system tested had 100% nylon tricot panties, a bra with an all nylon cup with elastic of nylon/spandex, panty hose of 100% nylon, leather shoes, and a wig of 100% vinyon.

Burn #15, which involved a FR treated wool pantsuit, consisted of three runs with three different ignition sites. Run 1, with ignition at the jacket hemline, had no flame spread or

damage beyond charring a small segment of the Nomex lining. However, Runs 2 and 3, with ignition sites close to the mannequin, produced heat input above 10 cal/cm^2 by 20 seconds. As seen on the TV tape, the fire burned through the FR polyester blouse near sensors #1 and #2 in Run 2 (see Figure B2), and sensors #13 and #14 on the back of the mannequin (see Figure B3), although it did not actually spread outside either ignition site.

In Burn #16, there was internal burning or smoldering of the FR rayon tunic and pants not seen visually but evidenced by smoke coming out of the V-neck of the jacket before visible flaming of the jacket front. Figure B4 shows sensor #2 peaking at 30, 45, and 60 seconds when there were small flames seen on jacket front. Sensor #1 was obviously receiving some heat input, although the flames never reached up to the chin.

As seen in Figure B5, Burn #17, Run 2 had heat pulse input with the second ignition attempt at the waistline. This ignition site was located higher on the muumuu than in Run 1, where the tab fell off and there was no flame spread or measured heat transfer. The heat transfer data on Figure B5 corresponds with what was seen visually. The fire was seen at the waistline nearest sensor #5, spreading upward, burning the dress and bra at the center front. Although the flames did not actually reach sensor #1 at the chin, the heat would have been sufficient to cause a second-degree burn.

The other polyester muumuu, tested in Burn #18, Run 2, when ignited under the bodice on the left side, showed heat pulse input to sensor #4 and more intense heat registered at the waistline on #5 than seen on the previous muumuu. This agrees with the observations made.
Again, #1 sensor at the chin registered high enough to have simulated a serious burn injury without direct flame contact. As the fire burned through at the center bodice, #2 sensor input went up rapidly at about 70 seconds.

Burn #19 involved a polyester body suit with a different skirt for each run number. In Runs 1 and 2, involving FR treated wool skirts, there was no char damage beyond the hem ignition site and both were extinguished by patting with a glove. On the third skirt, cut from an experimental FR polyester/FR rayon blend, there was some heat transfer to sensor #9 (see Figure B7) on the thigh in the area of the ignition source. There was no visible flame spread, and the smoldering of the charred area was put out with an asbestos glove at 90 seconds.

Figure B8 (Burn #20, Run 3) shows much the same burning behavior as just previously described for Burn #19. Again, three different skirts were tried in combination with a Nomex bodysuit. Runs 1 and 2, involving a FR 75 wool/25 polyester double knit skirt and a FR cotton skirt had no flame spread onto the skirt and the charred portion was equal to the area of the ignition site. In Run 3, a Nomex fabric, the same pattern was visible, but there was heat input to sensors #8 and #9 on the thigh, near the ignition source.

Burn #21 involved a FR rayon bodysuit with different skirts and an apron. Run 1 was in combination with a Kynol/Nomex woven skirt--charred area limited to the hemline ignition site. Run 2 was the same garment combination, but with the addition of a Nomex serving apron. Ignition was at the bottom of the apron just above the left knee. Some flame spread was seen from the tab up the front of the apron, producing the heat pulse input as seen in Figure B9. Notebook observations indicated a color change visible on the apron from navy blue to a rose color upon flame contact with the fabric. It was also noted that the charred area following CO_2 extinguishing was extremely brittle. Run 3, which involved a polyester double knit skirt was similar to Run 1 --the charred area limited to the hemline ignition site. Run 4 involved a second ignition attempt on the same garment combination as in Run 3. The site was high up on the left side by sensor #20. Visually, there was a slow flame spread and some melt-drip, which agrees with the heat transfer data as seen in Figure B10. The paper tab dropped off onto the right shoe shortly before 60 seconds, ending the burn.

FIGURE B1

LOCATION OF SENSORS IN FEMALE, SIZE 10 MANNEQUIN (GRI)

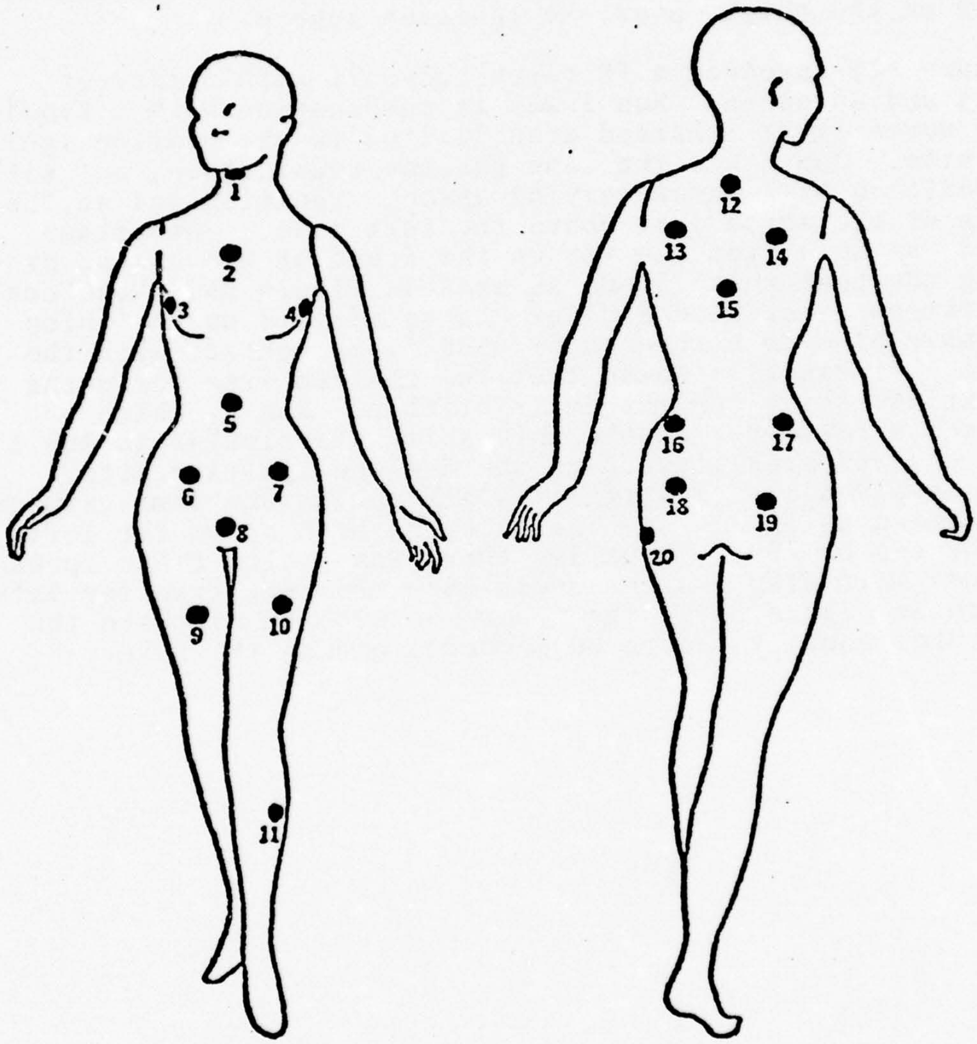


FIGURE B2

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #15 - RUN 2

Pantsuit of 100% wool double knit, FR treated with a Nomex lining; bodysuit of 100% polyester, FR treated

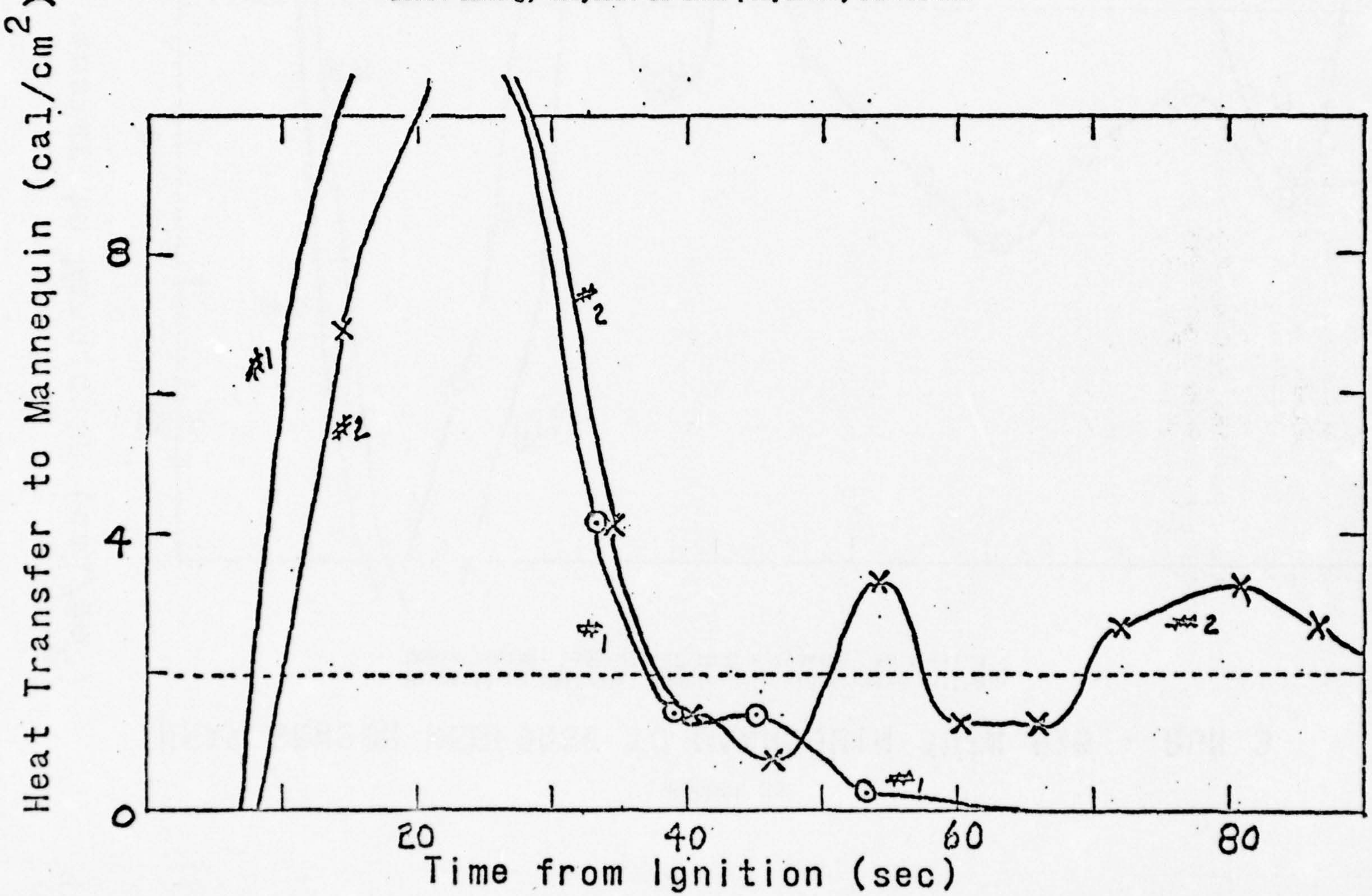


FIGURE B3

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #15 - RUN 3

Pantsuit of 100% wool double knit, FR treated with a Nomex lining; bodysuit of 100% polyester, FR treated

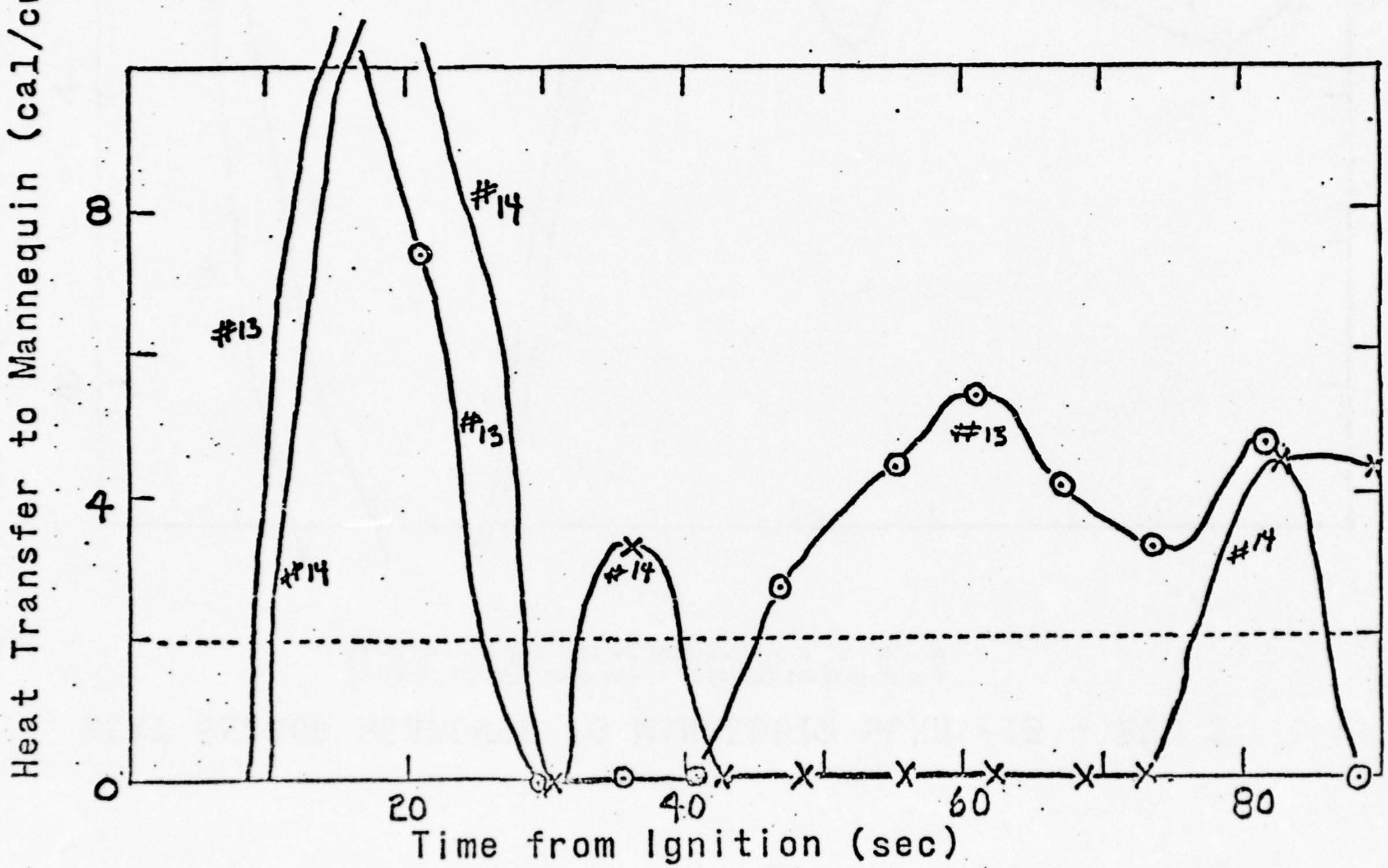


FIGURE B4

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #16 - RUN 1

Tunic and pants of 100% PFR rayon, basket weave, pink; the pants were lined with 100% Nomex

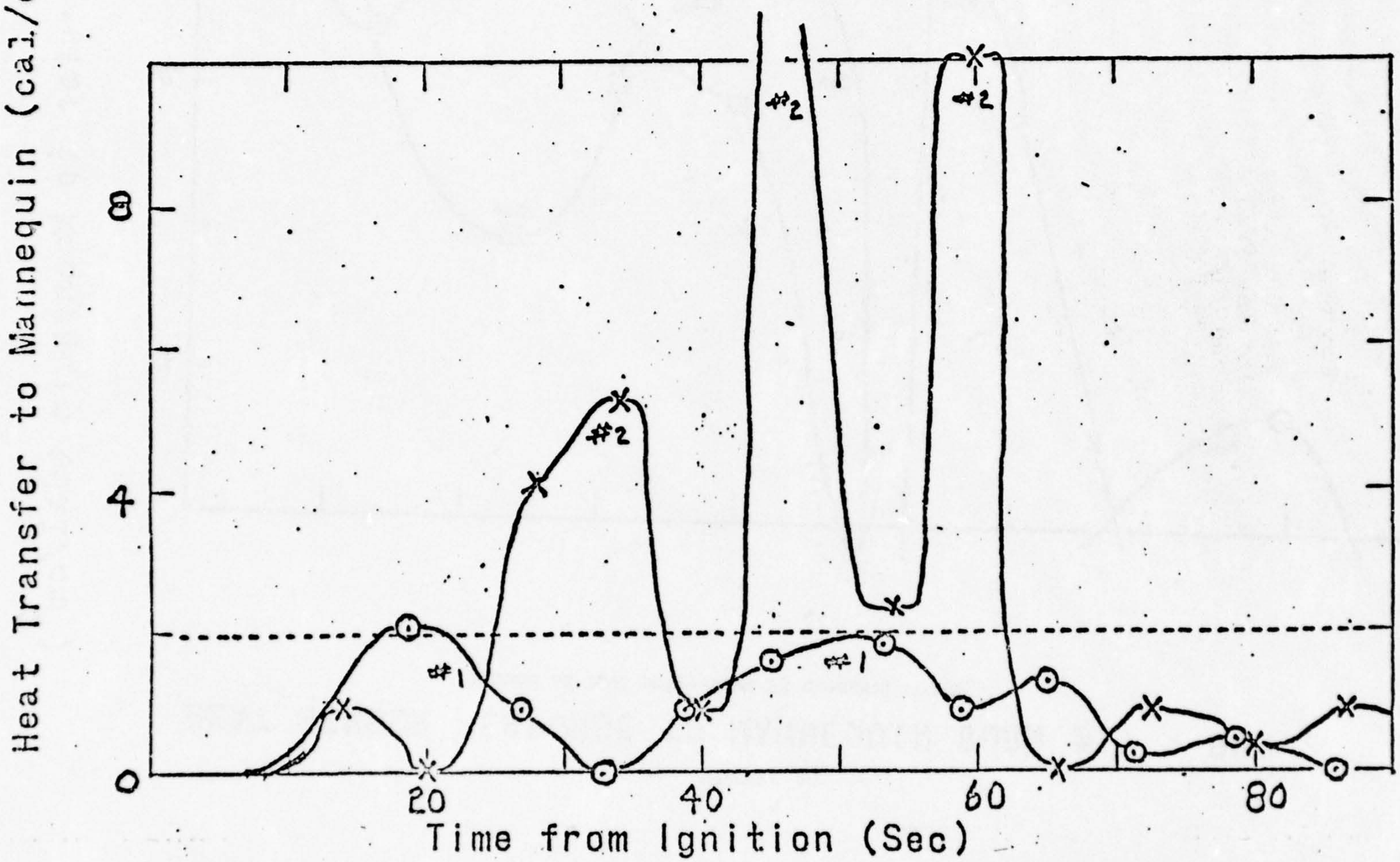


FIGURE B5

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #17 - RUN 2

Muumuu of 100% polyester, FR treated, woven

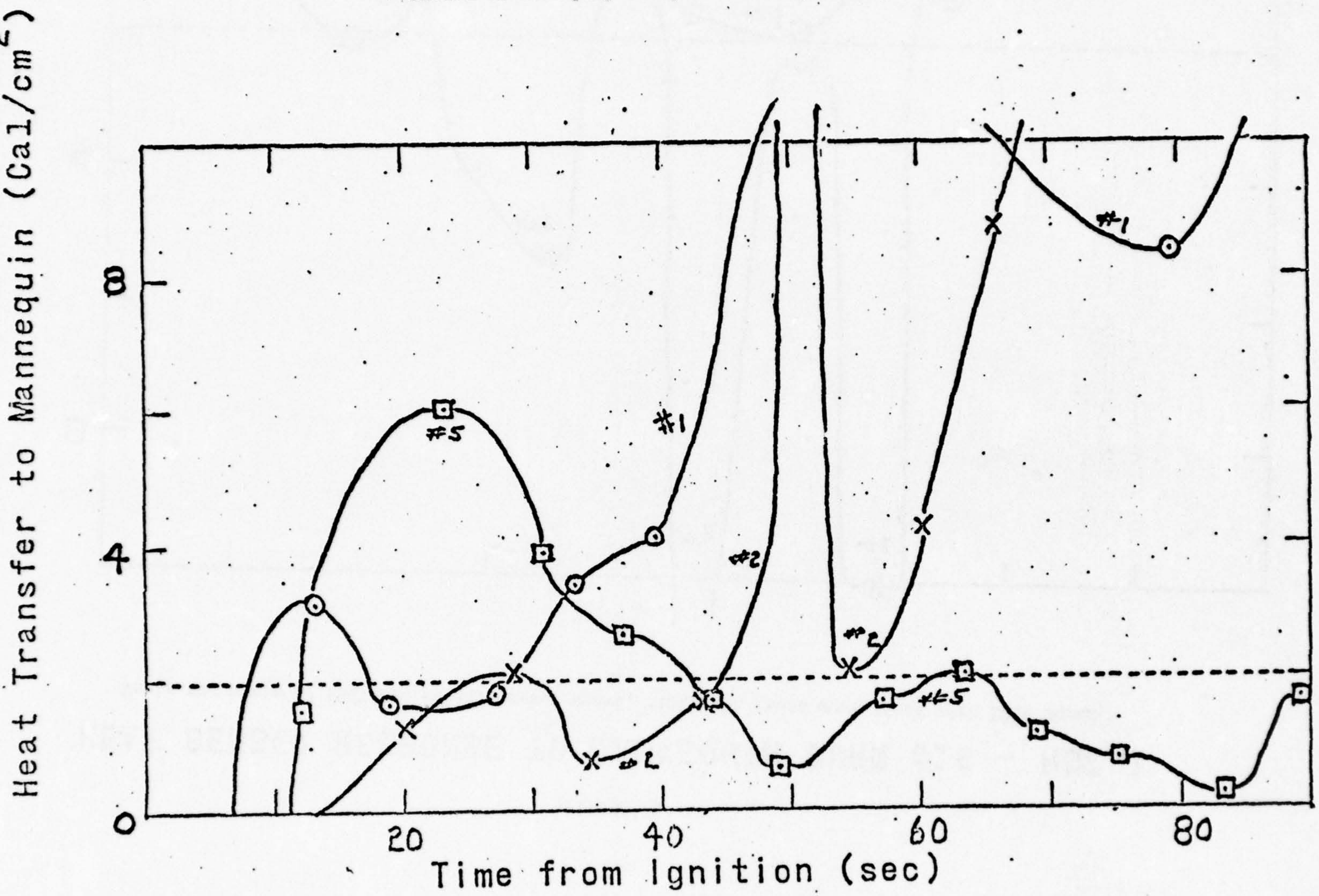


FIGURE B6

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #18 - RUN 2

Muumu of 100% polyester, FR treated, double knit

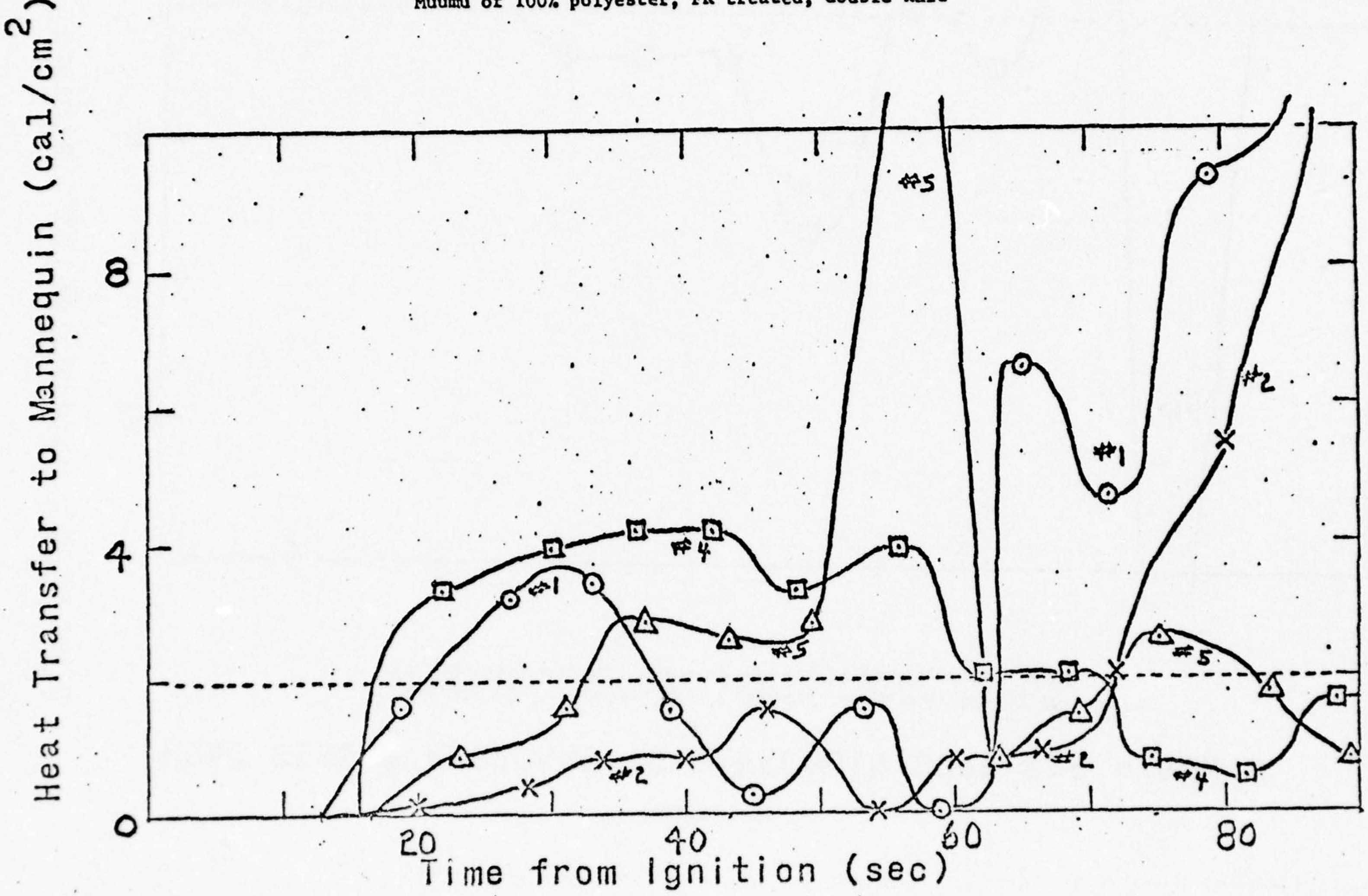


FIGURE B7

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #19 - RUN 3

Bodysuit of 100% polyester, FR treated, woven with bikini of 80% nylon/20% spandex; skirt of 65% PFR rayon/35% Dacron, woven

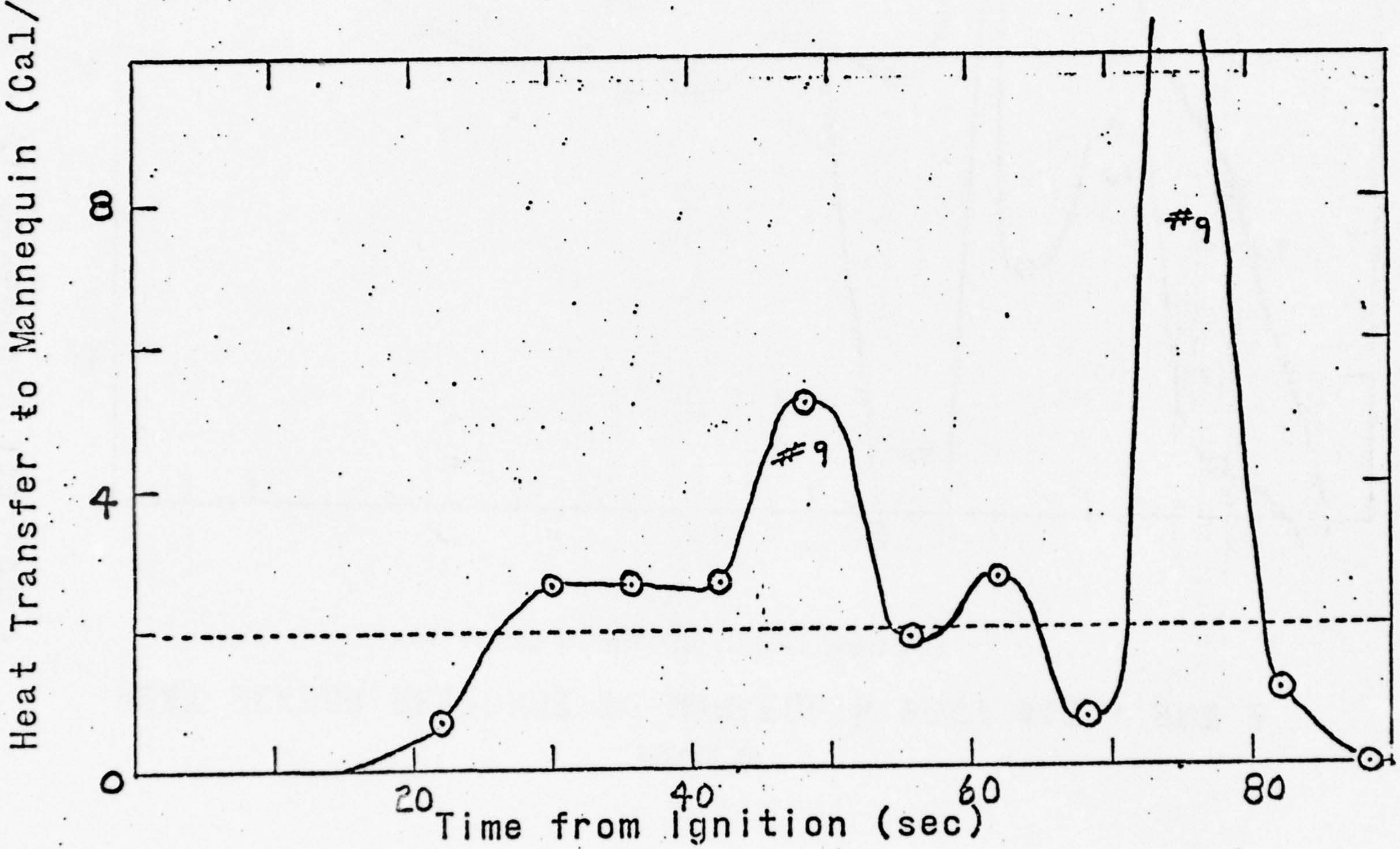


FIGURE B8

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #20 - RUN 3

Blouse of 100% Nomex, woven with bikini of 80% nylon/20% spandex; skirt of 100% Nomex, woven

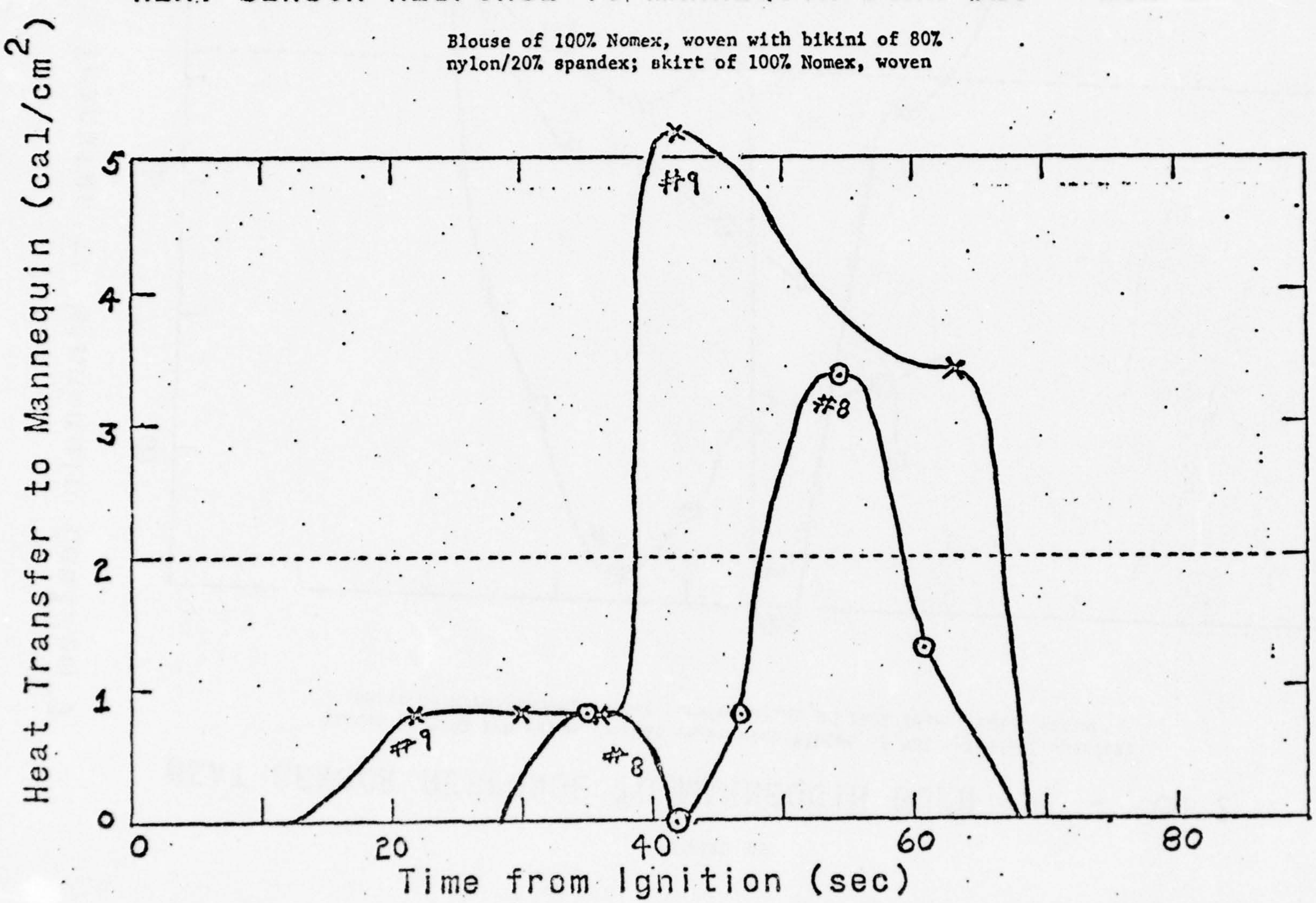


FIGURE B9

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #21 - RUN 2

Blouse of 100% PFR rayon, basket weave with bikini of 80% nylon/20% spandex; skirt of Kynol/Nomex, woven; serving apron of 100% Nomex, twill weave

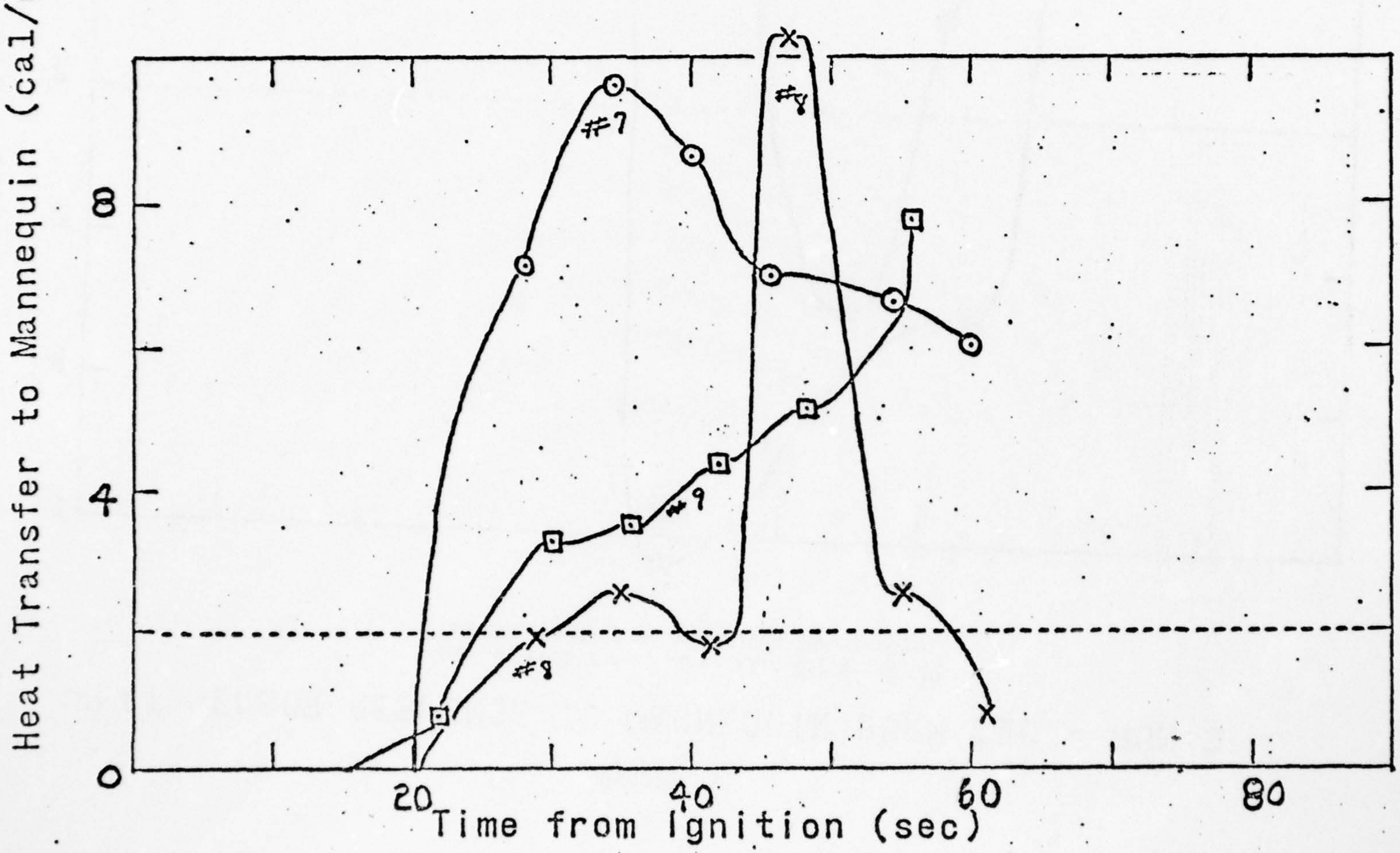
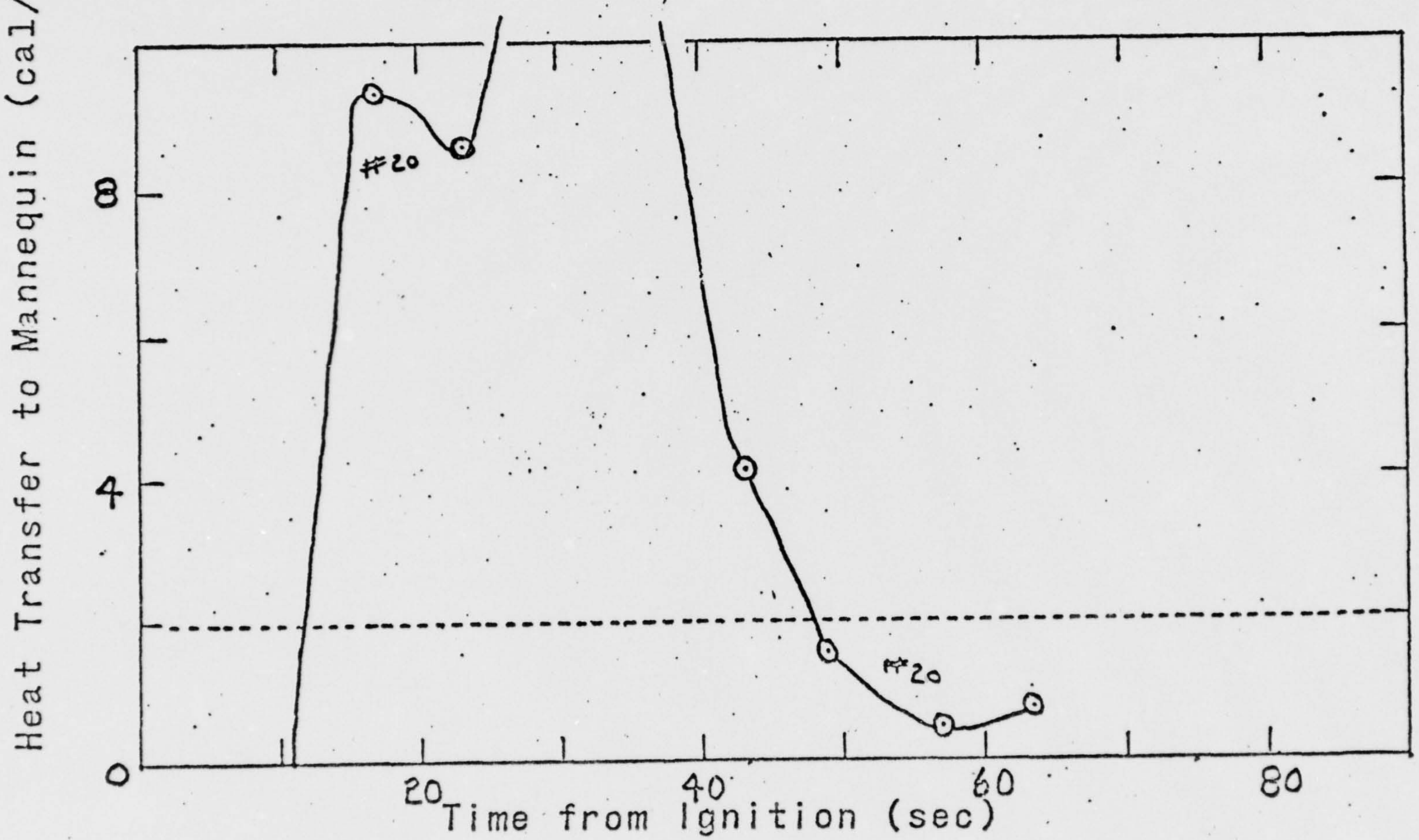


FIGURE B10

HEAT SENSOR RESPONSE TO MANNEQUIN BURN #21 - RUN 4

Blouse of 100% PFR rayon, basket weave with bikini of 80% nylon/20% spandex; skirt of 100% polyester, double knit



7. APPENDIX C

PROPOSED FLAMMABILITY STANDARD FOR FLIGHT ATTENDANT UNIFORMS

1. PREAMBLE

The duties of flight attendants (F/A's) include activities which may expose them to ignition sources and heat flux such as galley or lavatory fires during flight and cabin fires during evacuation of passengers in survivable crashes. It, therefore, appears that F/A uniforms should resist ignition and heat flux consistent with available technology and acceptable levels of comfort, serviceability, appearance, and cost. This standard sets test criteria to qualify such garments.

This standard covers only items presently considered part of F/A uniforms, as defined under 3.1. It does not cover items such as shoes, underwear, handbags, and wigs.

This standard specifies a two-step qualification of uniform items:

a flammability (self-extinguishment) test according to a well-established method, FF 5-74[1], modified as described in 4.1;

a heat flux resistance test according to a method described in 4.2, to estimate the protection afforded by the uniform item against heat flux during cabin fires.

2. SCOPE AND APPLICATION

2.1 This standard provides test methods and acceptance criteria to qualify the self-extinguishment characteristics of fabrics and uniform items exposed to ignition sources and to qualify their level of protection from heat flux in cabin fires.

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[1] Standard for the Flammability of Children's Sleepwear, Sizes 7 Through 14 (FF 5-74), Consumer Product Safety Commission, Federal Register, Vol. 39, No. 85, 15214-15227, May 1, 1974.

2.2 All uniform items defined under 3.1 are subject to the requirements of this standard.

3. DEFINITIONS

3.1 Uniform Items

Any garment worn by the F/A during duty, including but not limited to jackets, coats, vests, overcoats, raincoats, sweaters, shirts, blouses, slacks, skirts, dresses, capes, tunics, aprons, scarves, ties, and hats. Wigs, shoes, hose, underwear, etc., which are worn with the uniform but not generally obtained from the employing airline are excluded. Pocketbooks and luggage are also excluded.

3.2 Uniform Item Production Unit

All uniform items delivered under one purchase order and identical except for size.

3.3 Fabric Production Unit

Any quantity of finished fabric up to 4,600 linear meters (5,000 linear yards) which has a specific identity that remains unchanged throughout the unit except for color or print pattern as specified in 4.1.3.1.2. For purposes of this definition, finished fabric means fabric in its final form after completing its last processing step as a fabric except for slitting.

3.4 Fabric Piece

A continuous, unseamed length of fabric, one or more of which make up a production unit.

3.5 Fabric Flammability Test

The test method described in the "Standard for the Flammability of Children's Sleepwear, Sizes 7 Through 14 (FF 5-74)", which is designed to establish the flammability (self-extinguishment characteristics) of fabrics (see 4.1 below).

3.6 Heat Flux Resistance Test

A test procedure designed to measure the heat flux resistance of a single fabric or layer combinations used in uniform items (see 4.2 below).

3.7 Fabric Flammability Test Specimen

A 8.9 ± 0.5 x 25.4 ± 0.5 cm (3.5 ± 0.2 x 10 ± 0.2 in) section of fabric. If fabrics are used in multiple layer form in certain uniform items; e.g., lined skirts, the layers attached to each other as in the garment will constitute the required specimen.

3.8 Heat Flux Resistance Test Specimen

A section of fabric or multiple layers of fabrics (see 3.7) 15.2 ± 0.5 x 15.2 ± 0.5 cm (6 ± 0.2 x 6 ± 0.2 in).

3.9 Sample

A sample for the flammability test contains five specimens; for the heat flux resistance test, three specimens.

3.10 Char Length

The distance from the original lower edge of the specimen exposed to the flame in accordance with the procedure specified in 4.1.4.3.2.2 to the end of the tear or void in the charred, burned, or damaged area, the tear being made in accordance with the procedures specified.

3.11 Afterglow

The continuation of glowing of parts of a specimen after flaming has ceased.

3.12 Trim

Decorative materials such as ribbons, laces, embroidery, or ornaments. This definition does not include (a) individual pieces less than 2 inches in their longest dimension, provided that such pieces do not constitute or cover in aggregate

a total of more than 129 cm^2 (20 sq in) of the item or (b) functional materials (findings) such as zippers, buttons, or elastic bands used in the construction of garments.

4. TEST PROCEDURES

4.1 Fabric Flammability Test

4.1.1 Summary of Test Method

Conditioned specimens are suspended one at a time vertically in holders in a prescribed cabinet and are subjected to a standard flame along their bottom edges for a specified time under controlled conditions. The char lengths are recorded.

4.1.2 Test Criteria

The test criteria when the testing is done in accordance with Sampling and Acceptance Procedures, 4.1.3, and Test Procedure, 4.1.4, are:

4.1.2.1 Average Char Length

The average char length of five specimens shall not exceed 17.8 cm (7.0 in).

4.1.2.2 Full-Specimen Burn

No individual specimen shall have a char length of 25.4 ± 0.5 cm (10 ± 0.2 in).

4.1.2.3 Specimen Acceptance

Details of the number of specimens which must meet the above test criteria for unit acceptance are specified in Sampling and Acceptance Procedures, 4.1.3, below.

4.1.3 Sampling and Acceptance Procedures

4.1.3.1 General

4.1.3.1.1 The test criteria of 4.1.2 shall be used in conjunction with the following fabric and garment sampling plan.

4.1.3.1.2 Different colors or different print patterns of the same fabric may be included in a single fabric or uniform production unit, provided such colors or print patterns have been shown to comply with the Test Criteria, 4.1.2, and Sampling and Acceptance Procedures, 4.1.3, by previous testing of at least three samples from each color or print pattern to be included in the unit.

4.1.3.1.3 Each sample (five specimens) for Fabric Sampling (see 4.1.3.2 below) shall be selected so that two specimens are in one fabric direction (machine or cross-machine) and three specimens are in the other fabric direction, except for additional samples selected after a failure, in which case, all five specimens shall be selected in the fabric direction in which the specimen failure occurred.

4.1.3.1.4 Fabric samples may be selected from fabric as outlined in Fabric Sampling (see 4.1.3.2 below) or may be cut from uniform items randomly selected from each uniform item production unit. If the uniform item production unit exceeds 3,000 items, identical except for size, the number of samples used must be doubled; if it exceeds 6,000 items, tripled, etc.

4.1.3.2 Fabric Sampling

A fabric production unit is either accepted or rejected in accordance with the following plans:

4.1.3.2.1 Normal Sampling

Select one sample from the beginning of the first fabric piece (piece) in the unit and one sample from the end of the last piece in the unit or select a sample from each end of the piece if the unit is made up of only one piece. Test the two selected samples. If both samples meet all the test criteria of 4.1.2, accept the unit. If either or both of the samples fail the 17.8 cm (7.0 in) average char length criterion, 4.1.2.1, reject the unit. If two or more of the individual specimens, from the 10 selected specimens, fail the

25.4 cm (10 in) char length criterion (4.1.2.2), reject the unit. If only one individual specimen, from the 10 selected specimens, fails the 25.4 cm (10 in) char length criterion (4.1.2.2), select five additional specimens from the same end of the piece in which the failure occurred, all five to be taken in the fabric direction in which the specimen failure occurred. If this additional sample passes all the test criteria, accept the unit. If this additional sample fails any part of the test criteria, reject the unit.

4.1.3.2.2 Multiple Fabric Layer Sampling

If uniform items contain multiple layers; e.g., outer fabric, innerlining, and lining, and the area of such multiple layers exceeds 129 cm^2 (20 sq in) in the largest size uniform to be issued, the above sampling provisions (4.1.3.2) apply to such multiple layers tested in the same manner as fabrics.

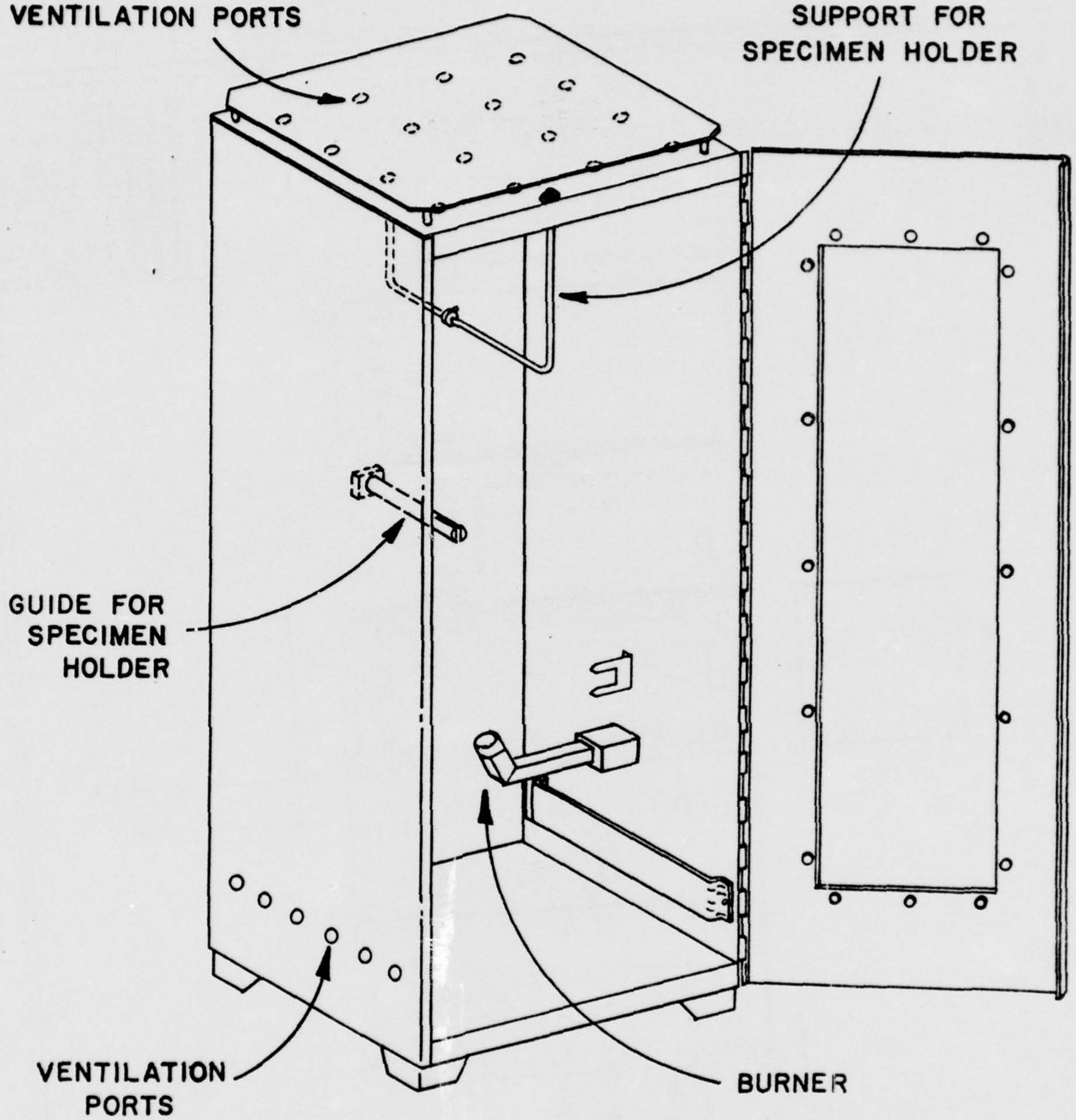
4.1.4 Test Procedure

4.1.4.1 Apparatus

The following test apparatus shall be used for the test. Alternate test apparatus may be used only with prior approval of the Federal Aviation Administration (FAA).

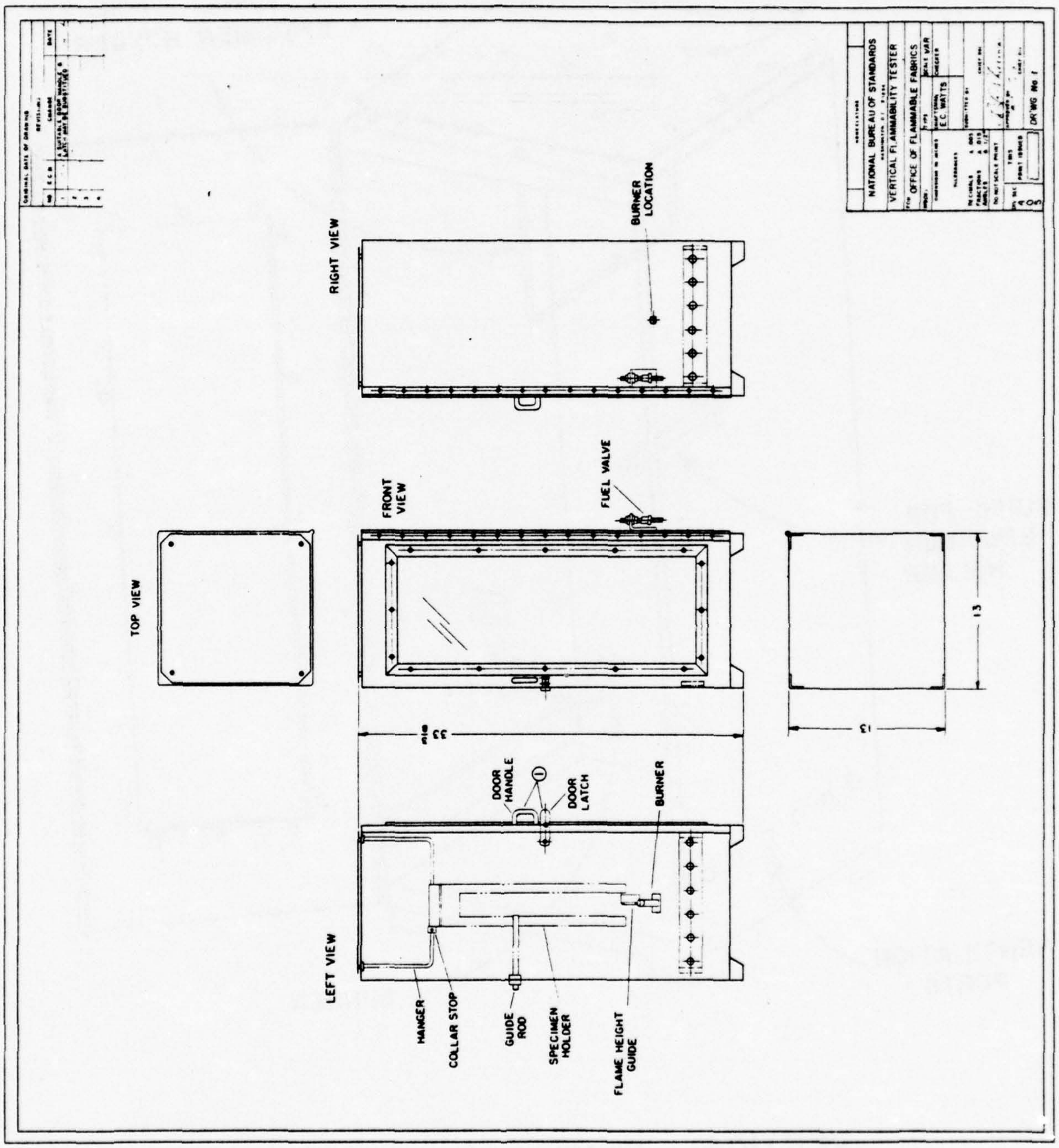
4.1.4.1.1 Test Chamber

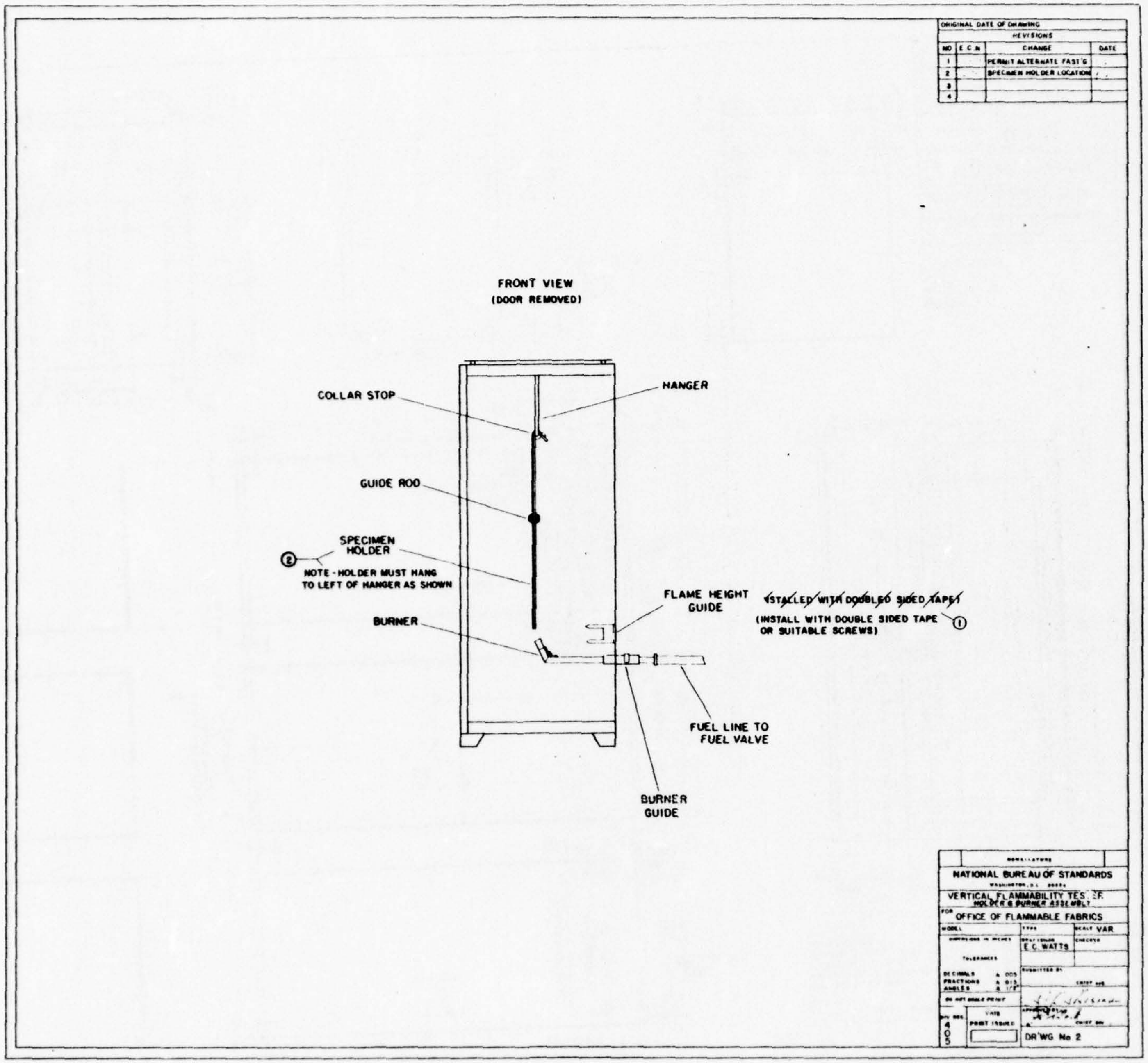
The test chamber shall be a steel cabinet with inside dimensions of 32.9 cm (12-15/16 in) wide, 32.9 cm (12-15/16 in) deep, and 76.2 cm (30 in) high. It shall have a frame which permits the suspension of the specimen holder over the center of the base of the cabinet at such a height that the bottom of the specimen is 1.7 cm (3/4 in) above the highest point of the barrel of the gas burner specified in 4.1.4.1.3 and perpendicular to the front of the cabinet. The front of the cabinet shall be a close-fitting door with a transparent insert to permit observation of the entire test. The cabinet floor may be covered with a piece of asbestos paper, whose length and width are approximately 2.5 cm (1 in) less than the cabinet floor dimensions. The cabinet to be used in this test method is illustrated in Figure 1 and detailed in Engineering Drawings Numbers 1 through 7.

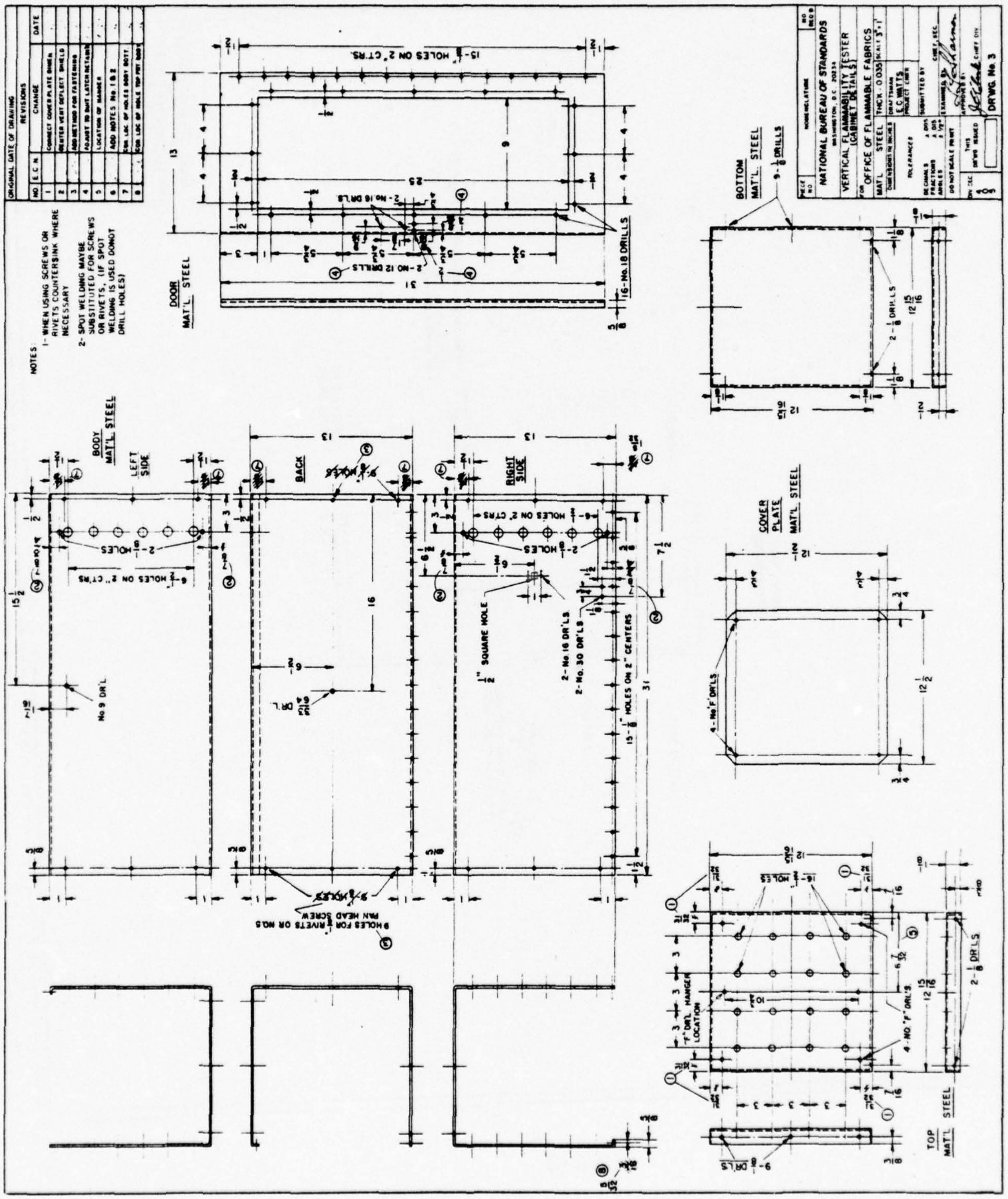


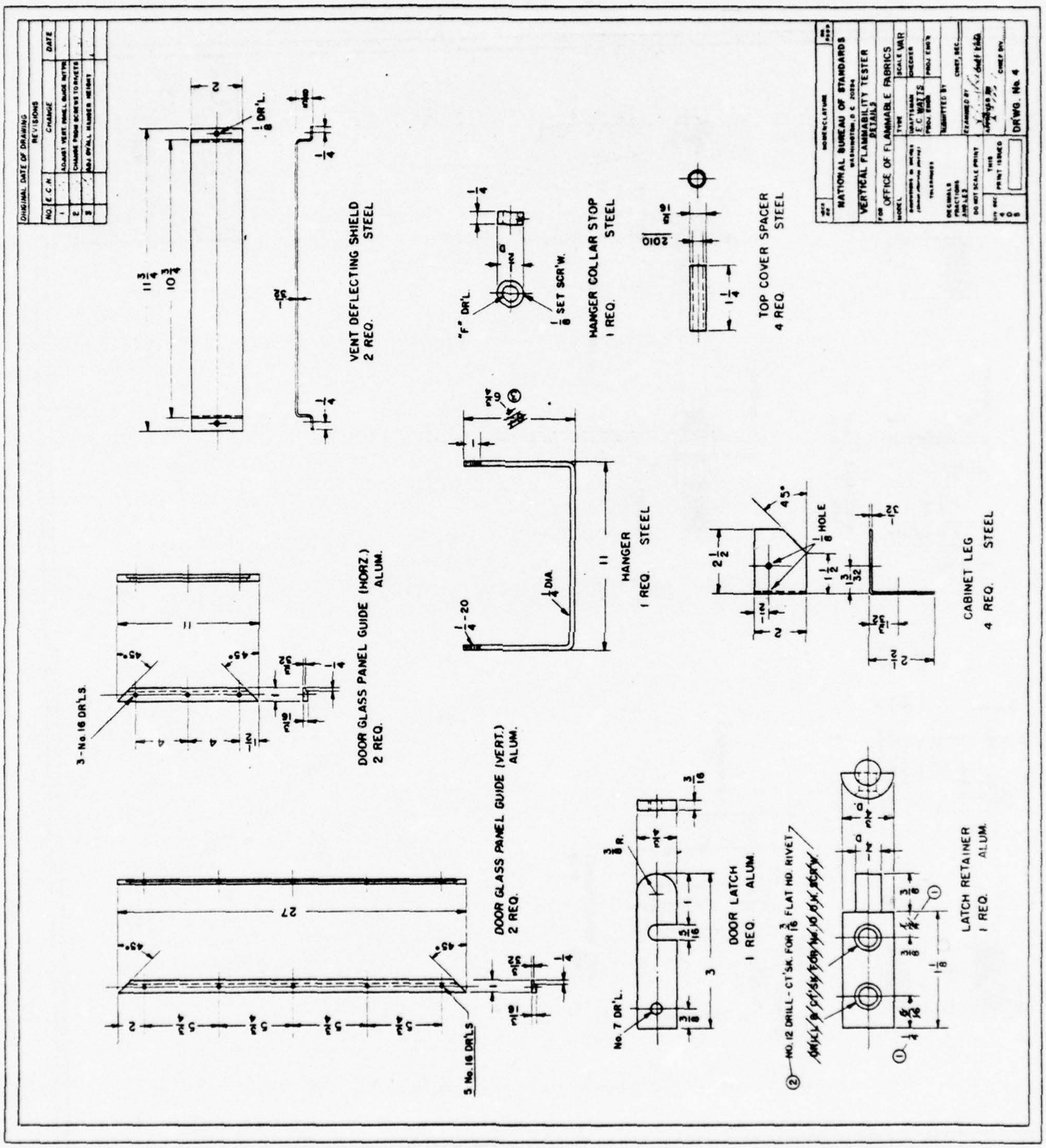
VERTICAL TEST CABINET

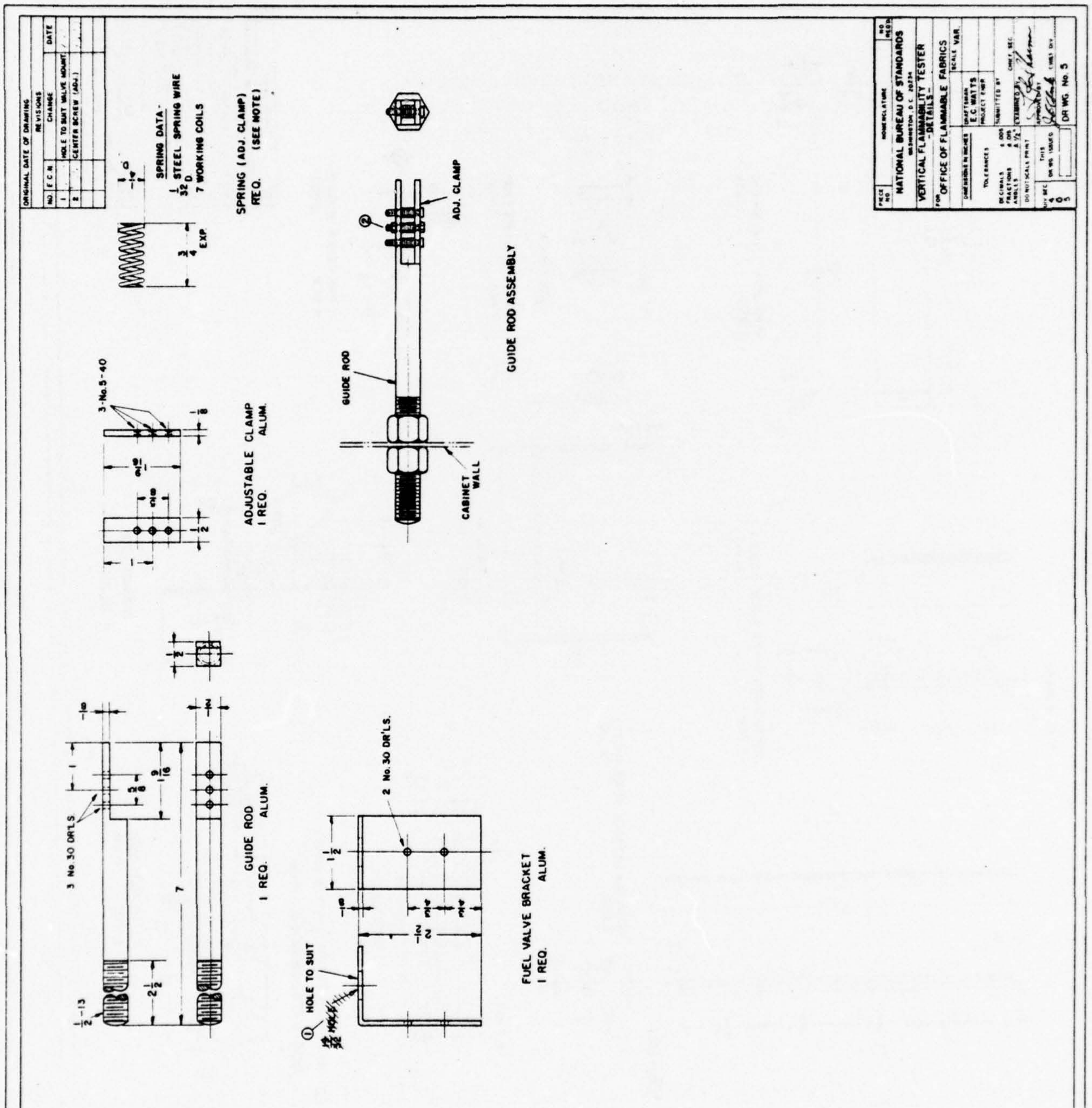
FIGURE I

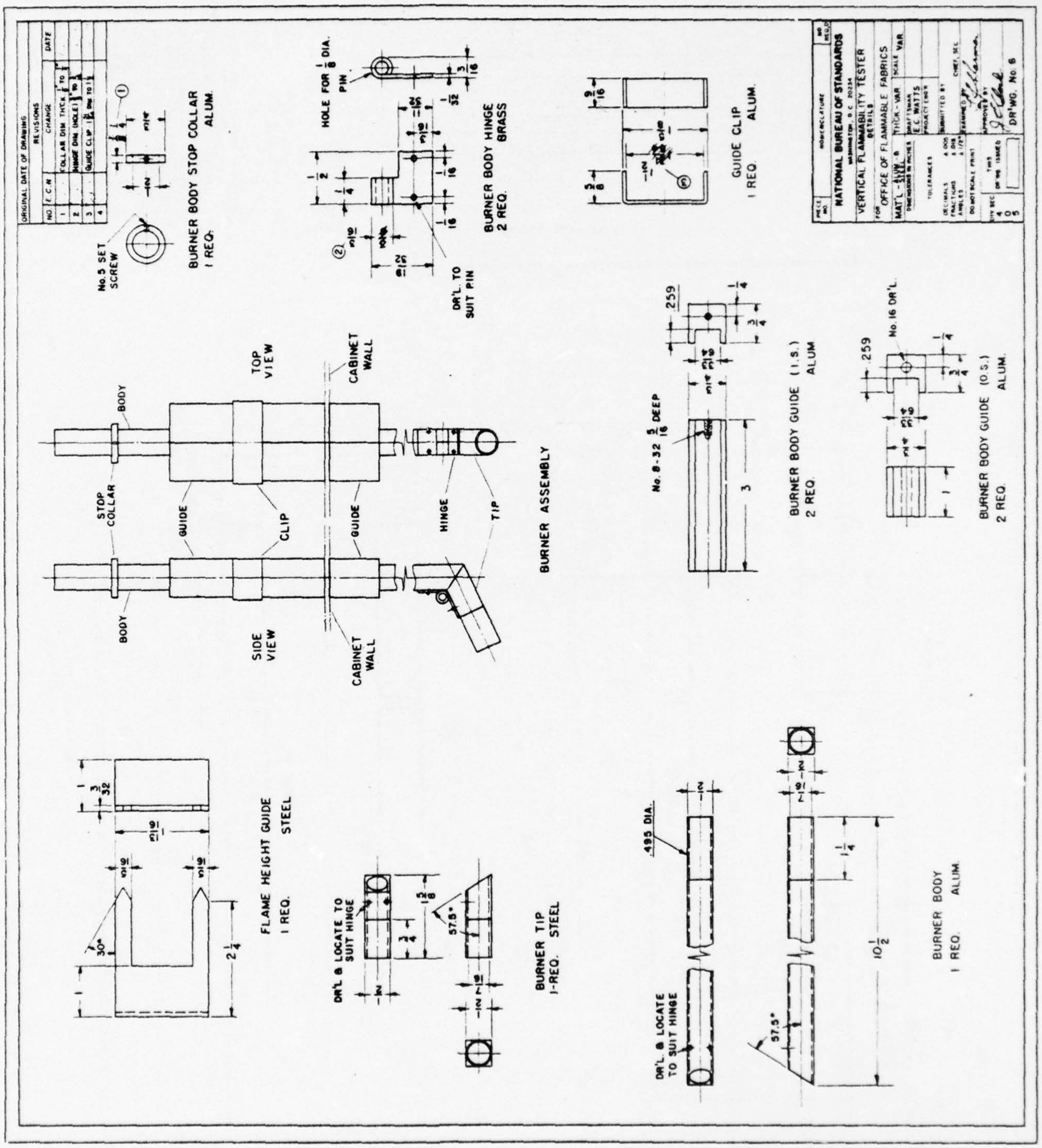

NATIONAL BUREAU OF STANDARDS
VERTICAL FLAMMABILITY TESTER
OFFICE OF FLAMMABLE FABRICS
E.C. WATTS
LEFT VIEW
HANGER
COLLAR STOP
GUIDE ROD
SPECIMEN HOLDER
FLAME HEIGHT GUIDE
BURNER
DOOR HANDLE
DOOR LATCH
TOP VIEW
FRONT VIEW
FUEL VALVE
RIGHT VIEW
BURNER LOCATION
33
13
13


ORIGINAL DATE OF DRAWING
REVISIONS
NO | E.C.N | CHANGE | DATE
1 | PERMIT ALTERNATE FAST'G
2 | SPECIMEN HOLDER LOCATION
FRONT VIEW
(DOOR REMOVED)
COLLAR STOP
HANGER
GUIDE ROD
SPECIMEN HOLDER
NOTE - HOLDER MUST HANG TO LEFT OF HANGER AS SHOWN
BURNER
FLAME HEIGHT GUIDE
~~INSTALLED WITH DOUBLED SIDED TAPE~~
(INSTALL WITH DOUBLE SIDED TAPE OR SUITABLE SCREWS)
FUEL LINE TO FUEL VALVE
BURNER GUIDE
NATIONAL BUREAU OF STANDARDS
VERTICAL FLAMMABILITY TESTER
HOLDER & BURNER ASSEMBLY
OFFICE OF FLAMMABLE FABRICS
SCALE VAR
E.C. WATTS
DR'WG No 2

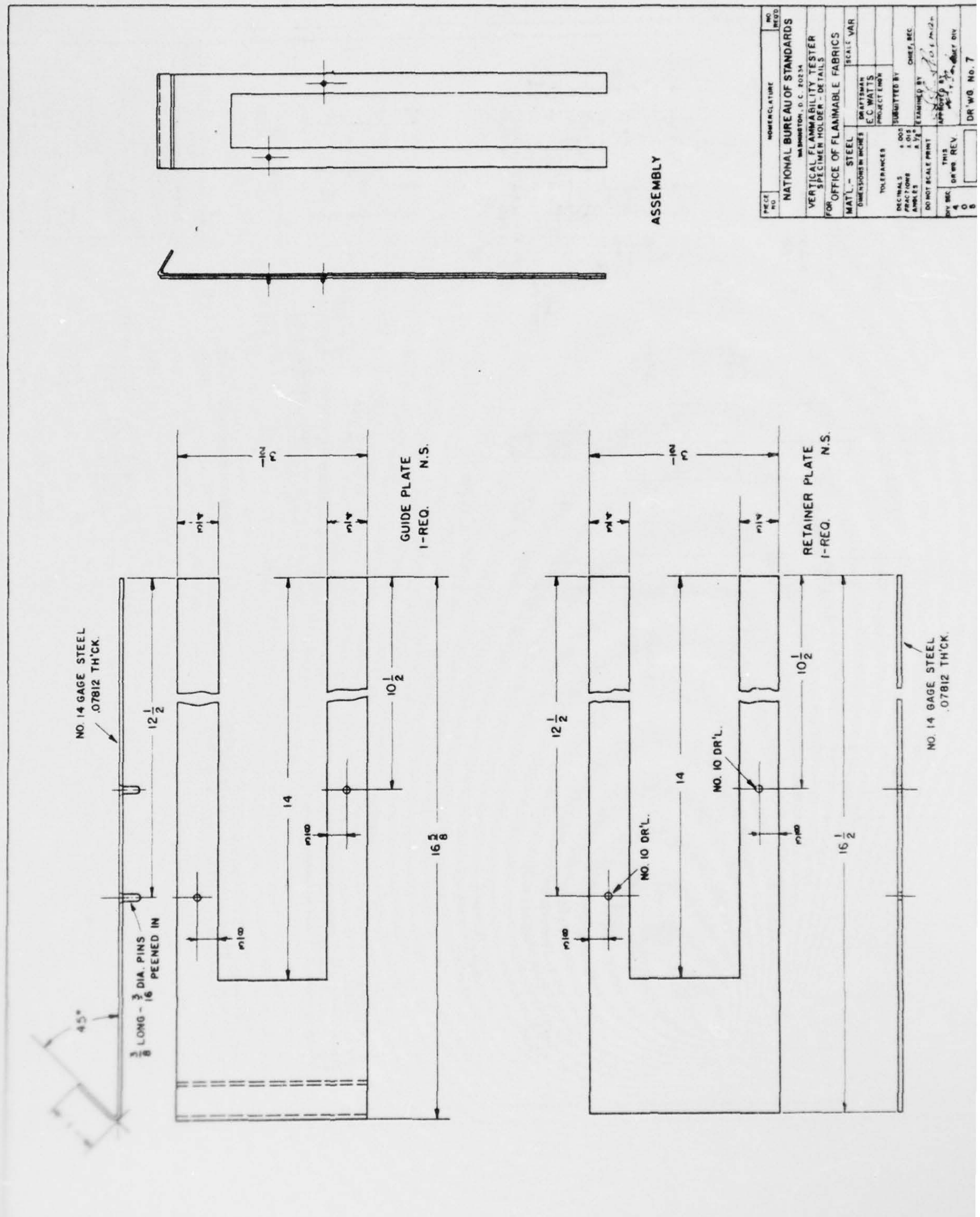

NOTES:
1- WHEN USING SCREWS OR RIVETS COUNTERSINK WHERE NECESSARY
2- SPOT WELDING MAYBE SUBSTITUTED FOR SCREWS OR RIVETS, (IF SPOT WELDING IS USED DO NOT DRILL HOLES)
DOOR MAT'L STEEL
BODY MAT'L STEEL
LEFT SIDE
BACK
RIGHT SIDE
BOTTOM MAT'L STEEL
COVER PLATE MAT'L STEEL
TOP MAT'L STEEL
NATIONAL BUREAU OF STANDARDS
VERTICAL FLAMMABILITY TESTER
(CABINET DETAILS)
OFFICE OF FLAMMABLE FABRICS
DRWG. No 3


NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234
VERTICAL FLAMMABILITY TESTER
DETAILS
OFFICE OF FLAMMABLE FABRICS
SCALE VAR
E.C. WATTS
DR'WG. No. 4
ORIGINAL DATE OF DRAWING
REVISIONS
NO
E.C.N.
CHANGE
DATE
ADJUST VERT. PANEL GUIDE PATTS
CHANGE FROM SCREWS TO RIVETS
ADJ OV'ALL HANGER HEIGHT
VENT DEFLECTING SHIELD
2 REQ. STEEL
HANGER COLLAR STOP
1 REQ. STEEL
"F" DR'L.
SET SCR'W.
TOP COVER SPACER
4 REQ. STEEL
DOOR GLASS PANEL GUIDE (HORZ.)
2 REQ. ALUM.
3-No.16 DR'LS.
HANGER
1 REQ. STEEL
DIA.
CABINET LEG
4 REQ. STEEL
HOLE
DOOR GLASS PANEL GUIDE (VERT.)
2 REQ. ALUM.
5 No.16 DR'LS
DOOR LATCH
1 REQ. ALUM.
No. 7 DR'L.
NO. 12 DRILL - CT'SK. FOR 3/16 FLAT HD. RIVET
LATCH RETAINER
1 REQ. ALUM.


GUIDE ROD
1 REQ. ALUM.
3 No. 30 DR'LS
ADJUSTABLE CLAMP
1 REQ. ALUM.
3-No.5-40
SPRING DATA
1/32 D STEEL SPRING WIRE
7 WORKING COILS
SPRING (ADJ. CLAMP)
REQ. (SEE NOTE)
HOLE TO SUIT
2 No. 30 DR'LS.
FUEL VALVE BRACKET
1 REQ. ALUM.
GUIDE ROD
CABINET WALL
ADJ. CLAMP
GUIDE ROD ASSEMBLY
ORIGINAL DATE OF DRAWING
REVISIONS
HOLE TO SUIT VALVE MOUNT
CENTER SCREW (ADJ.)
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234
VERTICAL FLAMMABILITY TESTER
-DETAILS-
OFFICE OF FLAMMABLE FABRICS
SCALE VAR.
DRAFTSMAN E.C. WATTS
DO NOT SCALE PRINT
DR WG. No. 5



NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234
VERTICAL FLAMMABILITY TESTER
DETAILS
FOR OFFICE OF FLAMMABLE FABRICS
MAT'L - ALUM. & STEEL
THICK - VAR
SCALE VAR
DIMENSIONS IN INCHES
DRAFTSMAN E.C. WATTS
TOLERANCES
DECIMALS ± .005
FRACTIONS ± .015
ANGLES ± 1/2°
DO NOT SCALE PRINT
DR'WG. No 6
ORIGINAL DATE OF DRAWING
REVISIONS
NO
E.C.N.
CHANGE
DATE
COLLAR DIM THICK
HINGE DIM (HOLE)
GUIDE CLIP
No. 5 SET SCREW
BURNER BODY STOP COLLAR ALUM.
1 REQ.
HOLE FOR 1/8 DIA. PIN
DR'L. TO SUIT PIN
BURNER BODY HINGE BRASS
2 REQ.
GUIDE CLIP ALUM.
1 REQ.
STOP COLLAR
BODY
GUIDE
CLIP
HINGE
TIP
TOP VIEW
SIDE VIEW
CABINET WALL
BURNER ASSEMBLY
No. 8-32 5/16 DEEP
.259
BURNER BODY GUIDE (I.S.) ALUM
2 REQ.
No. 16 DR'L.
BURNER BODY GUIDE (O.S.) ALUM.
2 REQ.
FLAME HEIGHT GUIDE STEEL
1 REQ.
30°
DR'L & LOCATE TO SUIT HINGE
57.5°
BURNER TIP STEEL
1-REQ.
.495 DIA.
DR'L & LOCATE TO SUIT HINGE
BURNER BODY ALUM.
1 REQ.


NO. 14 GAGE STEEL .07812 TH'CK.
3/8 LONG - 3/16 DIA. PINS PEENED IN
45°
GUIDE PLATE 1-REQ. N.S.
RETAINER PLATE 1-REQ. N.S.
NO. 10 DR'L.
12 1/2
10 1/2
14
16 5/8
16 1/2
ASSEMBLY
NATIONAL BUREAU OF STANDARDS
WASHINGTON, D.C. 20234
VERTICAL FLAMMABILITY TESTER
SPECIMEN HOLDER - DETAILS
FOR OFFICE OF FLAMMABLE FABRICS
MAT'L. - STEEL
SCALE VAR
DRAFTSMAN E.C. WATTS
DO NOT SCALE PRINT
DR'WG. No. 7

4.1.4.1.2 Specimen Holder

The specimen holder to be used in this test method is detailed in Engineering Drawing Number 7. It is designed to permit suspension of the specimen in a fixed vertical position and to prevent curling of the specimen when the flame is applied.

The specimen shall be fixed between the plates, which shall be held together with side clamps.

4.1.4.1.3 Burner

The burner shall be the same as that illustrated in Figure 1 and detailed in Engineering Drawing Number 6. It shall have a tube of 1.1 cm (0.43 in) inside diameter. The input line to the burner shall be equipped with a needle valve. It shall have a variable orifice to adjust the height of the flame. The barrel of the burner shall be at an angle of 25 degrees from the vertical. The burner may be equipped with an adjustable stop collar so that it may be positioned quickly under the test specimen. The burner shall be connected to the gas source by rubber or other flexible tubing.

4.1.4.1.4 Gas Supply System

There shall be a pressure regulator to furnish gas to the burner under a pressure of 103-259 mm. Hg. (2-5 lbs per sq in) at the burner inlet. (Caution: Precautionary laboratory practices must be followed to prevent the leakage of methane. Methane is a flammable gas which can be explosive when mixed with air and exposed to a source of ignition and can cause asphyxiation because of the lack of air.)

4.1.4.1.5 Gas

The gas shall be at least 97 percent pure methane.

4.1.4.1.6 Hooks and Weights

Metal hooks and weights shall be used to produce a series of loads for char length determinations. Suitable metal hooks consist of No. 19 gauge steel wire, or equivalent, made from 7.6 cm (3 in) lengths of the wire, bent 1.3 cm (0.5 in) from one end to a 45-degree angle hook. The longer end of the wire

is fastened around the neck of the weight to be used and the other in the lower end of each burned specimen to one side of the burned area. The requisite loads are given in Table 1.

Table 1

Original Fabric Weight[2]

Grams Per Square Meter	Ounces Per Square Yard	Grams	Ounces
Less than 101	Less than 3.0	54.4	2
101 to 207	3.0 to 6.0	113.4	4
207 to 338	6.0 to 10.0	226.8	8
Greater than 338	Greater than 10.0	340.2	12

4.1.4.1.7 Stopwatch

A stopwatch or similar timing device shall be used to measure time to 0.1 second.

4.1.4.1.8 Scale

A linear scale graduated in mm or 0.1-inch divisions shall be used to measure char length.

[2] Weight of the original fabric, containing no seams or trim, is calculated from the weight of a specimen which has been conditioned for at least 8 hours at 21 ± 1.1° C (70 ± 2° F) and 65 ± 2 percent relative humidity. Shortened conditioning times may be used if the change in weight of a specimen in successive weighings made at intervals of not less than 2 hours does not exceed 0.2 percent of the weight of the specimen.

4.1.4.1.9 Circulating Air Oven

A forced circulation drying oven capable of maintaining the specimens at 105 ± 2.8° C (221 ± 5° F), shall be used to dry the specimen while mounted in the specimen holders[3].

4.1.4.1.10 Desiccator

An air-tight and moisture-tight desiccating chamber shall be used for cooling mounted specimens after drying. Anhydrous silica gel with an indicator shall be used as the desiccant in the desiccating chamber. Replace or reactivate the desiccant when it becomes inactive.

4.1.4.1.11 Hood

A hood or other suitable enclosure shall be used to provide a draft-protected environment surrounding the test chamber without restricting the availability of air. This enclosure shall have a fan or other suitable means for exhausting smoke and/or toxic gases produced by testing.

4.1.4.1.12 Extinguishing Plates

Two extinguishing plates shall be used to extinguish afterglow. The plates shall be metal, approximately 35.6 x 5.1 cm (14 x 2 in) which fit within the opening of the specimen holder. The bottom plate shall be the thickness of the specimen holder, and the top plate shall be at least 0.32 cm (1/8 in) thick. A suitable metal specimen mounting block may be used for the bottom plate.

---

[3] Procedure 1(1.1.1) of ASTM D 2654-71, "Standard Methods of Test for Moisture Content and Moisture Regain of Textile Material", describes a satisfactory oven (1972 Book of ASTM Standards, Part 24, published by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

4.1.4.2 Mounting and Conditioning of Specimens

4.1.4.2.1 The specimens shall be placed in specimen holders so that the bottom edge of each specimen is even with the bottom of the specimen holder. Mount the specimen in as close to a flat configuration as possible. The sides of the specimen holder shall cover 1.9 cm (3/4 in) of the specimen width along each long edge of the specimen, and thus, shall expose 5.1 cm (2 in) of the specimen width. The sides of the specimen holder shall be clamped with a sufficient number of clamps or shall be taped to prevent the specimen from being displaced during handling and testing. The specimens may be taped in the holders if the clamps fail to hold them. Place the mounted specimens in the drying oven in a manner that will permit free circulation of air at 105° C (221° F) around them for 30 minutes[4].

4.1.4.2.2 Remove the mounted specimens from the oven and place them in the desiccator for 30 minutes to cool. No more than five specimens shall be placed in a desiccator at one time. Specimens shall remain in the desiccator no more than 60 minutes.

4.1.4.3 Testing

4.1.4.3.1 Burner Adjustment

With the hood fan turned off, use the needle valve to adjust the flame height of the burner to 3.8 cm (1-1/2 in) above the highest point of the barrel of the burner. A suitable height indicator is shown in Engineering Drawing Number 6 and Figure 1.

4.1.4.3.2 Specimen Burning and Evaluation

4.1.4.3.2.1 One at a time, the mounted specimens shall be removed from the desiccator and suspended in the cabinet

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[4] If the specimens are moist when received, permit them to air dry in laboratory conditions prior to placement in the oven. A satisfactory preconditioning procedure may be found in ASTM D 1776-67, "Conditioning Textiles and Textile Products for Testing", (1972 Book of ASTM Standards, Part 24, published by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103).

for testing. The cabinet door shall be closed and the burner flame impinged on the bottom edge of the specimen for 3.0 ± 0.2 seconds[5]. Flame impingement is accomplished by moving the burner under the specimen for this length of time and then removing it. Repeat test on five additional specimens, with 12 seconds ignition time.

4.1.4.3.2.2 When flaming has ceased, remove the specimen from the cabinet, except for specimens which exhibit afterglow. If afterglow is evident, the specimen shall be removed from the cabinet 1 minute after the burner flame is impinged on the specimen if no flaming exists at that time. Upon removal from the cabinet, the afterglow shall be promptly extinguished. The afterglow shall be extinguished by placing the specimen, while still in the specimen holder, on the bottom extinguishing plate and immediately covering it with the top plate until all evidence of afterglow has ceased. After removing the specimen from the cabinet and, if appropriate, extinguishing afterglow, remove it from the holder and place it on a flat clean surface. Fold the specimen lengthwise along a line through the highest peak of the charred or melted area; crease the specimen firmly by hand. Unfold the specimen and insert the hook with the correct weight, as shown in Table 1, in the specimen on one side of the charred area 6.4 mm (1/4 in) from the lower edge. Tear the specimen by grasping the other lower corner of the fabric and gently raising the specimen and weight clear of the supporting surface. Measure the char length as the distance from the end of the tear to the original lower edge of the specimen exposed to the flame. After testing each specimen, vent the hood and cabinet to remove the smoke and/or toxic gases.

4.1.4.4 Report

Report the value of char length, in centimeters (or inches), for each specimen, as well as the average char length for each set of five specimens and whether specimens have been washed or drycleaned.

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[5] If more than 30 seconds elapse between removal of a specimen from the desiccator and the initial flame impingement, that specimen shall be reconditioned prior to testing.

4.1.4.5 Durability Testing

In addition to being tested after one laundering and one drycleaning cycle, specimens shall also be tested after repeated laundering and drycleaning, as follows:

4.1.4.5.1 Items labeled "Launder Only": The items shall be laundered 50 times, before testing; additional items of the same type shall be drycleaned five times to assure that occasional nonconformance with the label does not affect the self-extinguishment characteristics of the item.

4.1.4.5.2 Items labeled "Dryclean Only": The items shall be drycleaned 20 times before testing; additional items of the same type shall be laundered 15 times before testing.

4.1.4.5.3 Laundering shall be done in conformance with AATCC Test Method 124-1969, Procedure III(B), Paragraphs 1-6[6], except that any commercial detergent may be used. Drycleaning shall be done in conformance with ASTM Standard Method D 2724-70[7].

4.2 Heat Flux Resistance Test

4.2.1 Summary of Test Method

Specimens are suspended one at a time, vertically, in holders located between a radiant heat source and a heat flux meter. The heat flux measured by the heat flux meter is recorded as a function of time.

4.2.2 Sampling Procedures

Samples of three specimens are obtained from single or multiple layers of fabrics as discussed in Fabric Sampling, 4.1.3.2, and Multiple Fabric Layer Sampling, 4.1.3.2.2. All specimens can be tested in the same direction. The fabric

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[6] Technical Manual of the American Association of Textile Chemists and Colorists, Vol. 46, 1970, or subsequent issues published by AATCC, P. O. Box 12215, Research Triangle Park, North Carolina 27709.

[7] 1970 Book of ASTM Standards or subsequent issues, Part 24, published by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

side worn on the outside of the uniform item must face the radiant source. If one specimen of a sample fails, take two more specimens from another sample. If both pass, the production unit passes. If one fails, the production unit fails.

4.2.3 Apparatus

4.2.3.1 Enclosure

A 51 x 51 cm (20 x 20 in) square, 61 cm (24 in) long, with the radiative source mounted approximately 10.3 cm (4 in) from one end, and open on the other end, made from asbestos cement board (Figure 2). A shutter located 5.1 cm (2 in) from the face of the radiative source is raised and lowered through a slot in the enclosure. A window in the enclosure permits observation of the specimen during the test. (Figure 3)

4.2.3.2 Radiant Heat Source

Vertically mounted, capable of producing a radiative heat flux field of 0.40 cal/cm^2 sec over an area of 7.6 x 7.6 cm (3 x 3 in) with temperature controller[8].

4.2.3.3 Heat Flux Meter

Range 0 to 0.5 cal/cm^2 sec ± 5 percent, water cooled, 1 cm in diameter, 150° viewing angle (minimum), mounted in a blackened 1.3 cm (1/2 in) thick asbestos cement plate, 12.7 x 12.7 cm (5 x 5 in) square (Figure 3).

4.2.3.4 Strip Chart Recorder

Suitable for use with above heat flux meter to obtain time/heat flux relationships, full-scale range 0-10 millivolt, chart speed of 30.4 cm (12 in)/minute or greater, with a full-scale response of at least 1 second.

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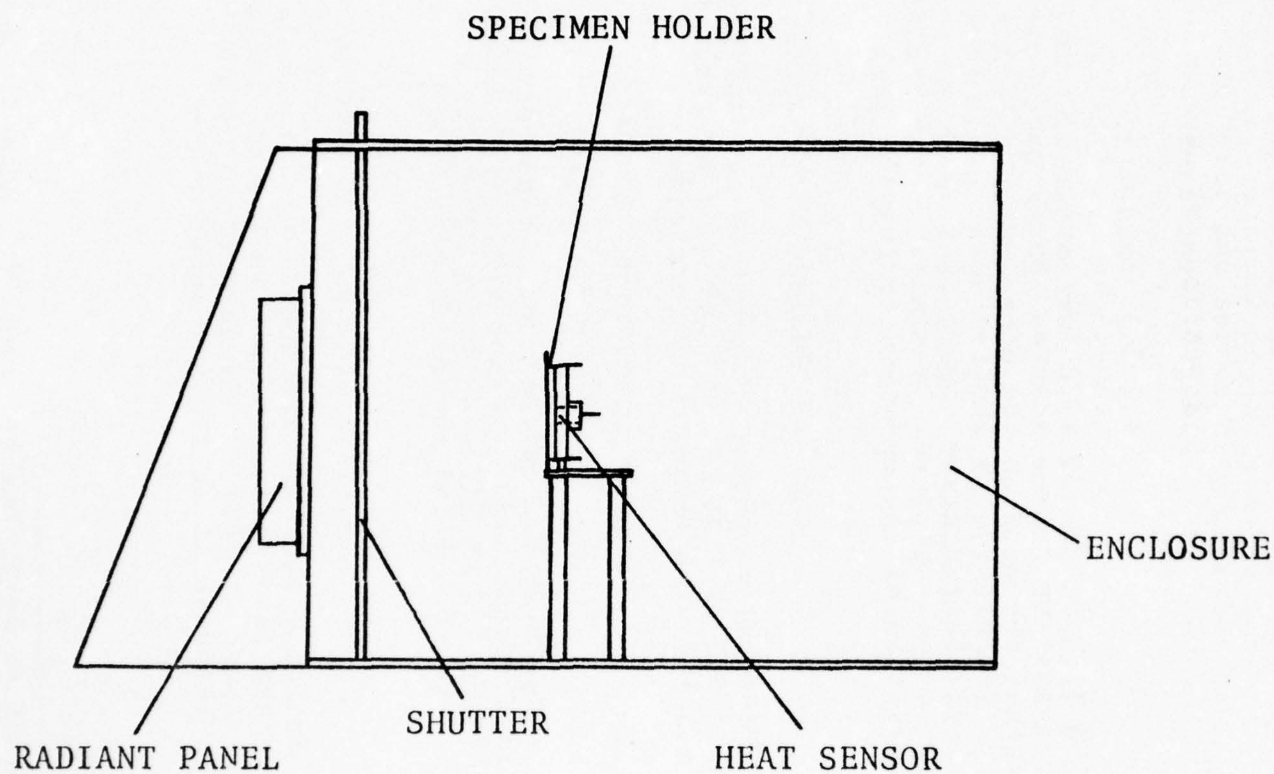
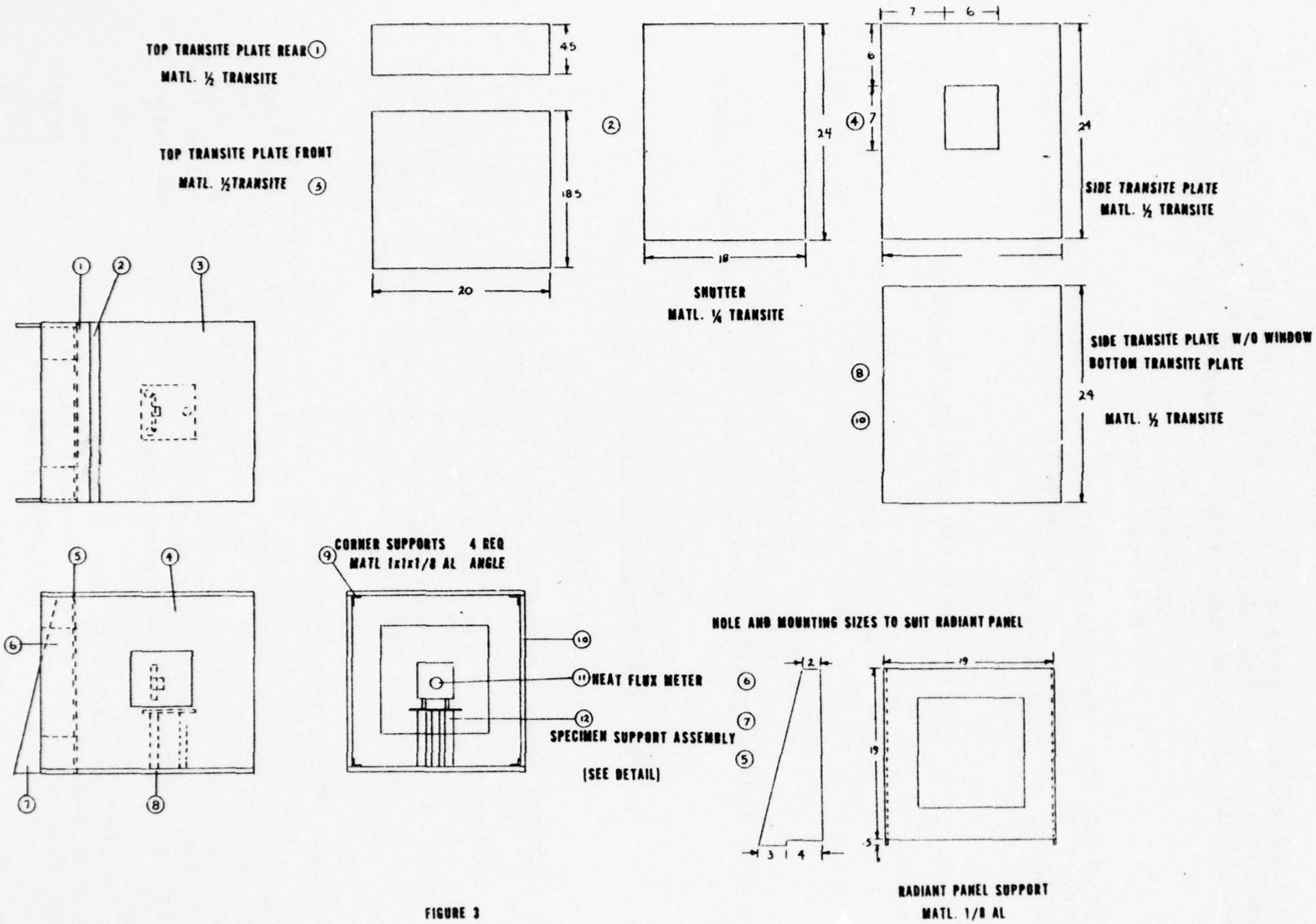
[8] A Casso-Solar Heater, Type "C", 31 x 31 cm (12 x 12 in), 0.77-6.2 watts/cm^2 (5-50 watts/sq in), Casso-Solar Corporation, 125-10 Queens Boulevard, Kew Gardens, New York 11415, or equivalent.

FIGURE 2: SCHEMATIC DIAGRAM OF APPARATUS TO MEASURE HEAT FLUX RESISTANCE





TOP TRANSITE PLATE REAR 1
MATL. ½ TRANSITE
TOP TRANSITE PLATE FRONT
MATL. ½TRANSITE 3
45
185
20
2
24
18
SHUTTER
MATL. ¼ TRANSITE
7
6
4
24
SIDE TRANSITE PLATE
MATL. ½ TRANSITE
8
10
SIDE TRANSITE PLATE W/O WINDOW
BOTTOM TRANSITE PLATE
MATL. ½ TRANSITE
CORNER SUPPORTS 4 REQ
MATL 1x1x1/8 AL ANGLE
9
HEAT FLUX METER
SPECIMEN SUPPORT ASSEMBLY
(SEE DETAIL)
HOLE AND MOUNTING SIZES TO SUIT RADIANT PANEL
19
RADIANT PANEL SUPPORT
MATL. 1/8 AL

FIGURE 3

4.2.3.5 Specimen Holders

Specified in Figure 4. One has guide slots so that the specimen can touch the sensor, the other has shorter guide slots so that the specimen-sensor distance is 1.2 cm (1/2 in).

4.2.3.6 Clips

For mounting specimens, GSA Supply Catalogue, Vol. 1, October 1975, binder clips with wire handles, small, 7510-00-223-2801, or equivalent.

4.2.3.7 Heat Insulating Gloves

4.2.3.8 Stopwatch

4.2.3.9 Filter Paper

Whatman filter paper #2, available from chemical supply houses.

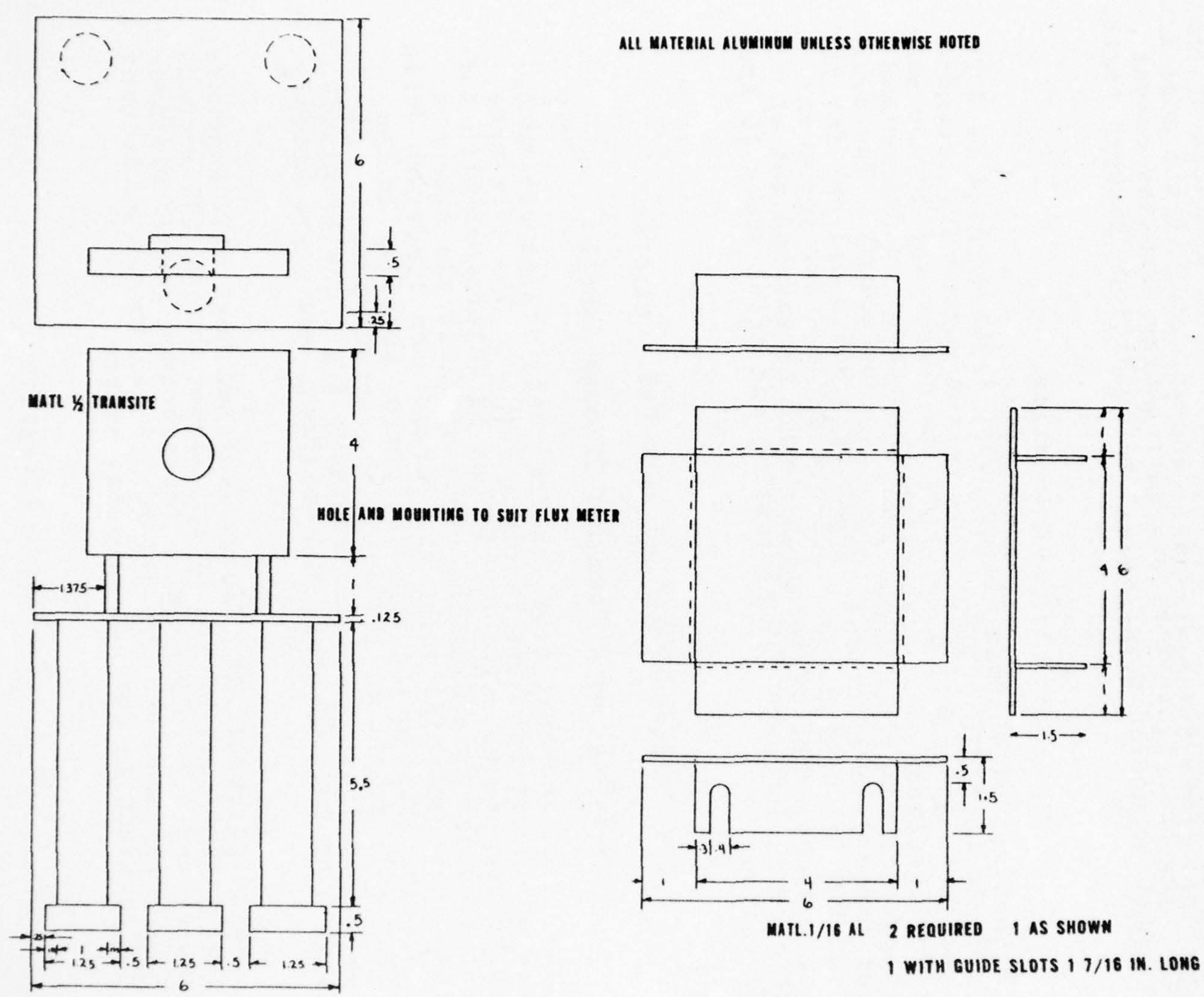
4.2.4 Test Procedure and Calibration

4.2.4.1 Test Procedure

The radiant heat source is adjusted to an operating temperature of 912° C (1,670° F) and allowed to reach equilibrium as indicated by a flat line on the strip chart recorder. Positions of the heat flux meter where the incident radiation is 0.20 cal/cm^2 sec and 0.40 cal/cm^2 sec are established and marked on the cabinet, and the specimens are later exposed at those positions.

Specimens are exposed with the warp or machine direction vertical. A specimen 15.2 x 15.2 cm (6 x 6 in) is attached to the specimen holder with four clips at the corners. The specimen holder is mounted on the frame holding the heat flux meter so that the specimen is 1.3 cm (1/2 in) in front of the heat flux meter or in contact with it. Three specimens are tested at each fabric-sensor distance.

The shutter in front of the radiative source is closed. The specimen holder is placed so that the specimen is exposed to a heat flux of 0.20 cal/cm^2 sec after the shutter is opened.



SPECIMEN SUPPORT ASSEMBLY DETAIL

FIGURE 4

SPECIMEN MOUNTING COLLAR

The time/heat flux relationships are recorded on the strip chart recorder for 2 minutes. Three additional specimens are exposed to 0.40 cal/cm^2 sec for 2 minutes, without use of the strip chart recorder, 1.3 cm (1/2 in) in front of the heat flux meter. The heat flux meter and surrounding asbestos cement plate must be cooled down to initial conditions between tests.

4.2.4.2 Calibration

A specimen of Whatman filter paper #2 is exposed to 0.20 cal/cm^2 sec heat flux. The total cal/cm^2 after 100 seconds for specimens 1.3 cm (1/2 in) from the sensor and for 35 seconds for specimens in contact with the sensor is determined by the method described under 4.2.5.1 (see below). The average of three determinations should be 4.9-5.1 cal/cm^2 for the 1.3 cm (1/2 in) distance and 3.2-3.4 cal/cm^2 for specimen-sensor contact. The calibration should be carried out at least once during each day of testing and after every 10 specimens tested.

4.2.5 Measurements and Pass-Fail Criteria

4.2.5.1 Heat Transfer Through Fabric

Time (sec) and heat flux (cal/cm^2 sec) scales are superimposed on the strip chart recorder graphs. The area under the curve represents cal/cm^2. It can be determined with sufficient accuracy by adding the areas of first the triangle and then the trapezoids which are formed when lines are drawn from the time axis to the recorded curve, parallel to the heat flux axis at the 5, 10, 15, . . . second points. Other methods, of at least the same accuracy; e.g., use of planimeter, cutting out the graph and weighing, etc., are acceptable.

A fabric passes if at 0.20 cal/cm^2 sec heat flux exposure, the total cal/cm^2 registered by the sensor during 100 seconds does not exceed 5.0 cal/cm^2 with the specimen-sensor distance 1.3 cm (1/2 in) and does not exceed 3.5 cal/cm^2 in 35 seconds with the specimen in contact with the sensor.

4.2.5.2 Fabric Integrity

Fabric production units fail if one of the specimens exposed for 10 seconds at 0.40 cal/cm^2 sec exhibits melt holes or char holes. Existence of a char hole will be established

by creasing the specimen across the exposed region by hand and placing the appropriate weight (Table 1) on the exposed creased region. If, upon removal of the weight, a hole has formed, the fabric production unit fails.

4.2.5.3 Report

Report the total heat flux exposure during 100 second exposure with the specimen-sensor distance 1.2 cm (1/2 in) and during 35 seconds with the specimen in contact with the sensor. Report hole formation, if any, and whether the specimens have been laundered or drycleaned.

5. RECORDS

The reports of the test results and the test specimens used in all tests performed under this standard must be retained by the airlines issuing or requiring the uniform items, for the service period of the uniforms. Such records shall include results of all tests, calibrations, sizes of all production units, etc. Test records shall be available for inspection by the FAA.

6. LABELING REQUIREMENTS

All uniform items shall be permanently labeled with care instructions, particularly with respect to limitations on laundering or drycleaning which may affect the flammability characteristics. They also shall be labeled with precautionary instructions to protect them from agents or treatments which are known to cause significant deterioration of their flame resistance. Such labels shall be permanent.

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